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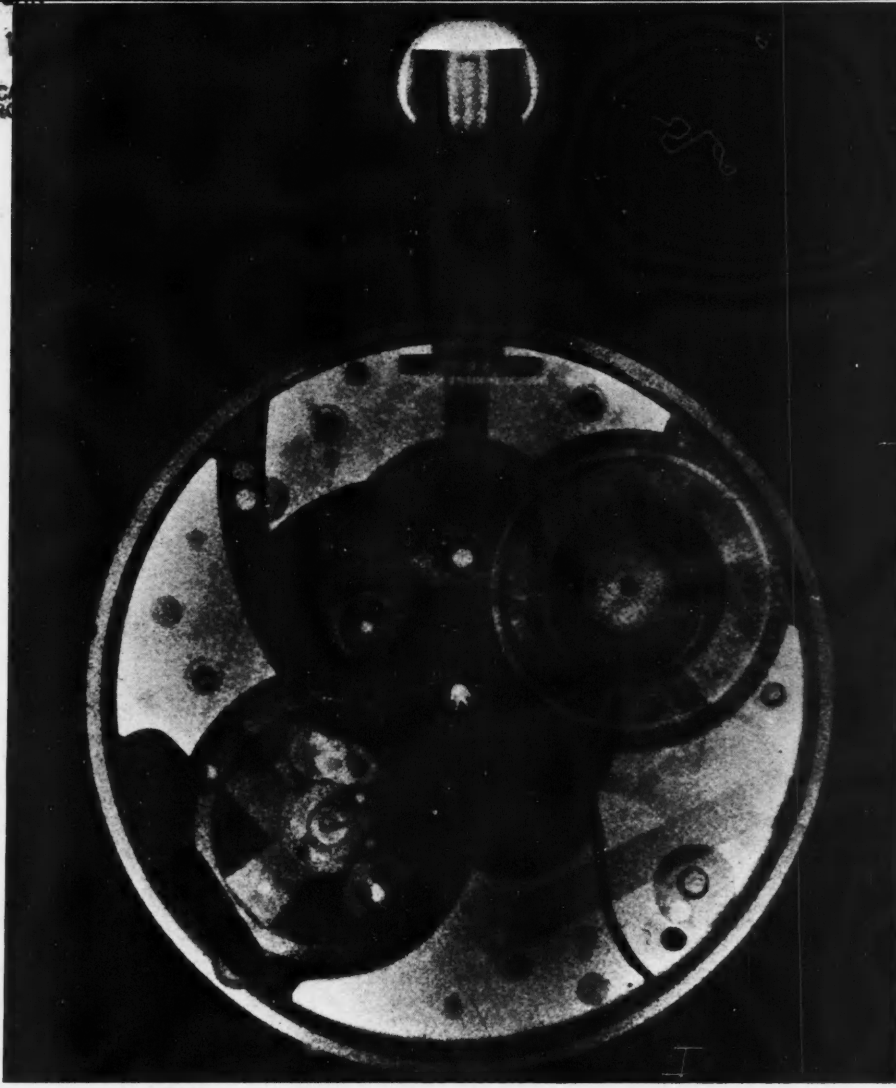

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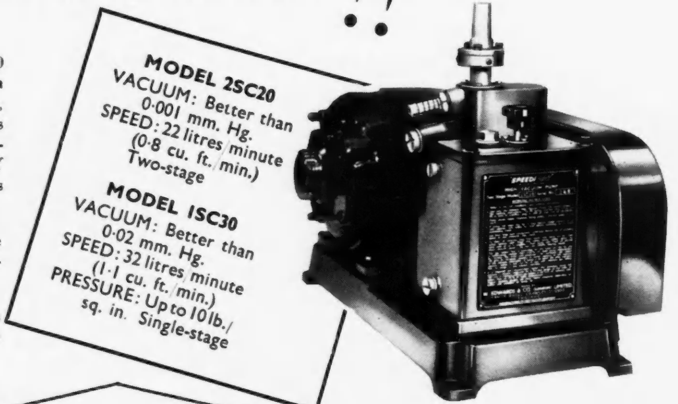

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THE MAGAZINE OF SCIENTIFIC PROGRESS

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THE PROGRESS OF SCIENCE

THE GENEVA CONFERENCE: AN ATOMIC MILESTONE

The United Nations conference on the peaceful uses of atomic energy which meets in Geneva from August 8 to 20 promises to be a most fruitful affair. In particular it should do a great deal of good by emphasising the importance of international co-operation in the development of atomic power and in other technical areas. There is no doubt that if the Atomic Age—using the term to mean the approaching era in which nuclear energy will be one of the most valuable sources of power—is to bring the maximum benefits to the whole world a high degree of international co-operation will have to be attained, through both bilateral and multilateral agreements. The need for this is obvious when one starts to consider the uneven distribution of the richer deposits of minerals from which the "fuel" elements of atomic power reactors can be derived. Without some measure of international co-operation over supplies of the essential raw materials the development of nuclear power will follow the unfortunate pattern of oil exploitation in its initial stages. Sir George Thomson said in 1945 that "without international control, I foresee a race for uranium making the race for oil look like a costers' Derby". The international *control* which so many scientists advocated at that time has not materialised, but its absence makes the need for international *co-operation* all the more urgent.

One arrives at the same conclusion if one starts thinking about the needs of the smaller countries which obviously cannot afford to establish well-equipped research and development laboratories on the Harwell scale. The scientists and technologists of such countries will be excluded from participation in the progress of nuclear science and technology unless special arrangements are made to ensure that they have access to modern research and development facilities. The favoured nations will gain much goodwill by sharing some of their facilities with them, which need not upset security arrangements in certain sectors of research. Harwell has made a limited start in that direction by opening its courses on radio-isotopes and power reactors to some experts from abroad, and so has the U.S. Atomic Energy Commission. One hopes that the countries with the best facilities will be able to share them with scientists of other nations to an increasing extent. There is room too for more joint enterprises like the Dutch-Norwegian atomic research unit at Kjeller, while the activities of CERN represent a new way in which international co-operation in the atomic field can be effected.

Sooner or later the United Nations will be bound to establish an International Atomic Energy Agency which could help to increase the speed with which technologically backward countries can come to enjoy the benefits of the Atomic Age. Last December the U.N. General Assembly accepted the idea of such an agency in principle, and after the Geneva conference it is certain to be brought up again as a detailed proposal capable of practical realisation.

Until such an agency materialises then, we must hope that the atomic energy policies of the individual nations will be as enlightened as that proposed by President Eisenhower this June when he put forward his "Atoms for Peace" scheme. He envisaged two parts to this new "technical aid" programme. Firstly, the U.S.A. would make available technical training and information to friendly nations prepared to invest their own funds in power reactors; secondly, the U.S.A. should pay half the cost of building research reactors in these countries. This would mean among other things that the U.S.A. would make uranium available to other countries, and already America has set aside 200 kilograms of enriched uranium for such use. In addition the Congressional Joint Committee on Atomic Energy has recommended the allocation of 5 million dollars to finance the President's scheme, which has been described as an act of generosity in direct descent from the Marshall Plan.

So far Britain has not come forward with a comparable scheme of technical assistance, but it is being argued that we cannot afford not to do so. *The Economist*, for example, published a strong leader on this theme which ended with these words: "Whether it be in Europe or in the outer world, the tempo of atomic affairs is speeding up. The game is usually won or lost in the early trials, and unless the British Government looks upon Mr. Eisenhower's proposal as a challenge to go and do likewise, we shall be missing tricks that we should be taking."

Besides the various bilateral atomic agreements and the unwritten bilateral arrangements that already exist between various countries, there already exists in the form of a detailed draft a U.S. proposal for the establishment of an international agency to serve as a "clearing house" for exchanging data, equipment and resources on atomic energy development. This is one move towards the setting up of an International Atomic Agency, which might operate as a specialised agency of the United Nations somewhat comparable to the World Health Organisation or F.A.O.

Doubtless the delegates to the Geneva conference will be talking about this idea, but the public discussions about it will have to be confined to the scientific and technical aspects. No decision about the establishing of an International Atomic Agency can be taken at this conference which is solely concerned with scientific and technical matters. The political aspects of atomic energy development are outside its terms of reference. Nor will the conference pass any resolutions or approve any recommendations.

The conference sessions which the general public throughout the world will learn most about, through the Press and radio, will most certainly be those sessions dealing with atomic power. Here the scientific and technological experts will be discussing such matters as the general role of atomic power in the economic development of both industrialised and non-industrialised countries, and the details of power-reactor construction (including their estimated cost). Britain's plans in this field of practical power production will command the keenest attention all over the world, for our plans are probably nearer to practical realisation than any of the plans worked out elsewhere. Some of the American papers to these sessions should also be noteworthy. Russian spokesmen have been talking about atomic power stations of 100,000 kilowatts now under construction in the U.S.S.R., but their statements up to now have been extremely bald and have therefore done no more than whet the curiosity of experts in other countries. If the Russian papers at Geneva go into practical details about these power stations, then they are going to arouse a great deal of interest.

This scientific and technical conference has been organised on a grand scale. Over 50 countries are sending delegations, and something like 700 scientists and technologists are expected to attend. In all some 300 papers are due to be read at Geneva, and some 600 more will be included in the published proceedings of the conference. Britain has submitted just over one hundred papers; of these, 67 will be read at the conference, the corresponding figures for the U.S.A. and the U.S.S.R. being about 170 and 70 respectively. Britain's official delegates at Geneva will be Sir John Cockcroft, Sir Christopher Hinton, Dr. J. F. Loutit, Sir George Thomson and Dr. Willis Jackson of Metropolitan-Vickers.

In addition to the lectures and discussions, visitors to Geneva will have a chance of seeing the two important exhibitions that have been organised in connexion with the conference. One of them is housed in the Palais des Nations, and is intended primarily for the scientists attending the conference as official delegates. In this exhibition Britain's Atomic Energy Authority is staging an exhibit featuring nuclear reactors, their use in research and power generation, and their special instrumentation.

The other exhibition, in the Palais des Expositions, will be seen by the general public as well as the delegates. This will include exhibits organised by such national agencies as our A.E.A. and the U.S. Atomic Energy Commission. Commercial firms are also exhibiting, with the result that the whole exhibition will have something of the character of an "Atomic Trade Fair". Some newspapers have been conveying the impression that Britain will not be well represented in this "trade fair", but in actual fact there are good reasons for believing that our exhibits (occupying nearly 30,000 square feet) will bear very favourable comparison with the big exhibits of America (covering about 40,000 square feet), Russia and France. Among the principal industrial firms from Britain that are exhibiting are Metro-Vick, English Electric, G.E.C., Taylor Woodrow and Babcock & Wilcox. The last-mentioned firm, which supplied the boilers for the first of Britain's atomic power stations, deserves particular note, for it has designed a most imaginative stand for Geneva, including designs for a mobile atomic power station sufficiently compact to be transported by rail, an atomic unit to provide electric power for irrigation plants in arid areas and an atomic ship.

Ten firms belonging to the Scientific Instrument Manufacturers' Association are co-operating in a joint display of their latest nucleonic equipment and other instruments indispensable to atomic research and development. Other enterprising instrument firms are staging separate exhibits, and these include Isotope Developments, E. K. Cole and Philips Electrical.

The participation of commercial firms in this second exhibition brings home the fact that the building of nuclear power stations is going to be big business. The time is coming when there will be large foreign orders to be fulfilled, and many of these orders should come to Britain, for the British firms who are involved in the big power programme worked out by the Atomic Energy Authority and the British Electricity Authority will have a head's start over most of their competitors in other countries. The more enterprising firms are already making plans which should enable Britain to obtain a fair share of export business in the nuclear engineering field. The extent to which British industry

is getting involved in the atomic business was well demonstrated by the remarkable list published by the *Financial Times* on June 27 giving the names of companies engaged in atomic power development and related activities. No less than 186 firms were listed, and that figure was increased to 208 with a supplementary list printed by that paper on July 7.

NEW INDUSTRIAL USES FOR FISSION PRODUCTS

One session of the Geneva conference will be devoted to the industrial utilisation of the ionising radiation from fission products. One example of this type of process is the irradiation of polythene to improve such properties as heat resistance. Up till now such processes have been tried on only a relatively small and experimental basis, but they promise to become of considerable industrial importance in the near future when large power reactors will be operating and will be providing, as by-products, huge amounts of fission products. The radiation from such sources in Britain will be equivalent to hundreds of times more than the radiation from all the radium the world has yet produced.

Much of the knowledge relevant to this kind of industrial application of fission products has been collected in Britain and the U.S.A. The U.K. Atomic Energy Authority considers the possibilities in this field so important that it has just established a new unit known as the Technological Irradiation Group to concentrate on the development of such applications. This unit comes within the Isotope Division, of which Dr. Henry Seligman is head, and it is expected to expand rapidly: a new site is already being sought where adequate laboratories can be built against the time when the new group will have outgrown the present accommodation available at Harwell.

The chemical industry is keenly interested in this line of work, for exciting discoveries have already emerged from studies of the effects of irradiation on a variety of chemical processes. One example: when acetylene is bombarded with β-particles, it polymerises to form benzene, and in one set of experiments the process worked with an efficiency of about 20% at a temperature of only 26°C. The chlorination process involved in the synthesis of the insecticide BHC is accelerated by radiation, and it looks as though it will be possible in time to exploit industrially many irradiation effects of this kind, which may gain something of the importance that catalysts now have in the chemical industry.

A good deal of experimental work has been done to test the application of ionising radiation from fission products to problems of food preservation. Large doses of radiation can do the sort of job which can be done by heat sterilisation in the canning industry, and smaller doses can achieve a milder effect comparable to that of pasteurisation. Initial experiments with radiation from fission products, and with electron beams from linear accelerators and Van de Graaf machines, are fairly promising, though no one would be rash enough to claim to have worked out a perfect process for preserving foodstuffs. Sterilisation by radiation

The new Astronomer Royal, Dr. Richard van der Riet Woolley, who succeeds Sir Harold Spencer Jones on January 1, 1956. He was Chief Assistant at Greenwich before going to Australia and becoming Commonwealth Astronomer and Director of the Commonwealth Observatory on Mount Stromlo.

seems to upset the flavours of food very considerably, and it is noteworthy that at the Press conference called to announce the formation of the new Technological Irradiation Group the Harwell experts did not attempt to refute the statement of the science correspondent who said that all the radiation-sterilised foods he had eaten were "completely inedible" because their flavour had been ruined. There seems to be a future for the technique of using smaller doses of radiation which can kill putrefactive bacteria on the surface of meat and fish without any adverse effect on the rest of the flesh. Radiation is undoubtedly effective when it comes to stopping vegetables such as onions and potatoes from sprouting, and this technique is probably safer than the use of "synthetic hormones" for this purpose. The British Navy is at present testing the storage life of vegetables that have been inhibited by radiation treatment at Harwell. No one in Britain knows more about the possibilities in this field than Dr. R. S. Hannan of the Low Temperature Research Station at Cambridge, whose excellent report setting out all the pros and cons of irradiation techniques for food preservation has just been published.* In contrast to many of the extravagant claims made for such techniques, Dr. Hannan's report errs on the side of caution—which is most desirable since he is dealing with the preservation of foods, and it has not yet been established beyond doubt that chemical changes occurring during or after the radiation process of sterilisation do not bring about the formation of toxic or harmful products.

* Food Investigation Special Report No 61: *Scientific and Technological Problems involved in using Ionising Radiations for the Preservation of Food,* 192 pp., published by H.M.S.O. for D.S.I.R., price 7*s.* 6*d.*

Another example of what radiation can do is provided by the case of transistors. Some of the properties of germanium are altered by irradiation, and transistors based on irradiated germanium give a better performance in some respects.

It must be stressed that nearly all of these examples of "technological irradiation" are only a very early development stage. But in the months to come a great deal of exciting experimentation and development work will be done at Harwell, and its results will be awaited with great interest by British industry.

HEAVY WATER PILES

Two new heavy water reactors will soon make an important contribution to facilities already available at the Atomic Energy Research Establishment, Harwell. The first, originally known by its engineering job number, E.443, has just been named DIDO. It was described in the recently published book entitled *Atomic Energy Research at Harwell*. The second, known at R.E.775 before being given the name of PLUTO, was not mentioned in that document, but was referred to by Sir John Cockcroft in his James Forrest Lecture to the Institution of Civil Engineers.

This second reactor represents a completely new departure as far as Harwell is concerned in that it is specifically designed for "loop" experiments, that is to say, for the testing of whole units and assemblies under conditions of high neutron flux. There will be facilities for six such loops to operate contemporaneously in six different separately shielded bays arranged around the reactor. It will be possible, for example, to test out a new liquid metal coolant complete with all its pumps and apparatus in one bay, while in another an experiment might be carried out to investigate over a period the feasibility of continuous processing in a particular homogeneous system.

Because of the time needed to conduct loop experiments in BEPO, the more powerful of the two graphite-moderated research reactors at Harwell, much of this work for the British project has had to be carried on in the past in NRX, the larger of the two heavy water piles at Chalk River, by courtesy of the Canadians.

Heavy water, of course, offers the greatest neutron economy known to be possible, but it is expensive and supplies are limited. Chiefly for these reasons, the British project had been running nearly nine years before it acquired last year its first heavy water reactor, DIMPLE (Deuterium Moderated Pile Low Energy). DIMPLE is very much like ZEEP, the first Commonwealth reactor, built under Dr. L. Kowarski's inspiration at Chalk River and completed in the autumn of 1945. It is extremely simple and consists of a large aluminium tank filled with heavy water and surrounded by a graphite reflector. Canned elements, control rods and safety rods all dip down into the water from above. Power is limited to a few watts and only the minimum of shielding is required. Even the fuel elements themselves acquire little activity over short periods of operation, and it is possible to withdraw them and rearrange the core of the reactor in a matter of days.

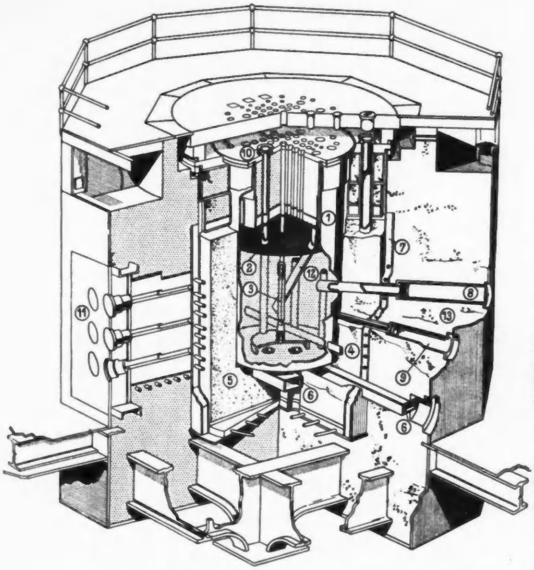
E.443 and R.E.775 instead have each a rating of about 10 megawatts, rather more than BEPO, and a peak neutron flux of 10^{14} per sq. centimetre per second, which is about 50 times that of BEPO. This means in effect that a job that took a year in the graphite reactor will be able to be performed in one week in one of the new heavy water reactors, while fuel elements that were normally changed every two years will now be removed every fortnight. This reduction in the time-factor will be of tremendous importance at a time when the development of better fuel elements is of paramount importance.

In general design, E.443 is very much like the pile called C.P.5 at the Argonne National Laboratory, Chicago. Head Wrightson Processes Ltd. collaborated in the design and are the principal contractors concerned with its construction. The fuel elements of E.443 are to be of enriched uranium in aluminium containers, and the heavy water will be used as a coolant as well as a moderator. To provide additional space for irradiation and for various experiments the inner core will be surrounded by successive concentric reflectors of heavy water and graphite. Around this last cylinder there is a water-cooled thermal shield surrounded in turn by a biological shield of concrete.

Aluminium "thimbles" protrude into the heavy water or graphite to provide space for irradiation of samples or apparatus. Control of the reactor is achieved by six cadmium-plated steel signal arms that are hinged near the circumference of the tank just above the water-level and dip down into the centre of the tank.

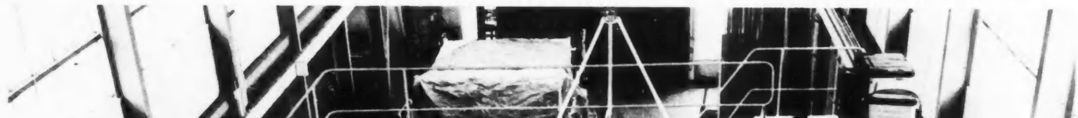
While the designing, building and commissioning and the subsequent operation of low energy reactors with fluxes in the region of 10^{12} neutrons per sq. centimetre per second is a fairly straightforward business that can be undertaken safely by any competent group of scientists and engineers, an increase in the flux by a factor of 10 exposes immediately a number of major technological difficulties, and when fluxes of a still higher order of magnitude are required safety conditions and operation become serious problems. The stage is then reached when, if the reactor is shut down and the coolant stopped, the fuel elements will be ruined or even melted in a very short time by fission-product heating. Where the reactor has been operating for a period of months at high power without a change of fuel elements, the radioactivity accumulated in the fission products will be considerable and, if canning fails, this may represent a substantial hazard over a wide area.

An example of the damage that may be done in a sudden heat-up or "power surge" is provided by the case of Canada's NRX pile (see DISCOVERY, August 1954). The accident to that pile occurred on December 12, 1952, and it caused failure of the sheathing of about 10% of the uranium fuel rods, accompanied by oxidation and some melting. The containing vessel was damaged beyond repair and 10,000 curies of radioactive fission products equivalent to 10 kilograms of radium, were discharged into the cooling water below the reactor. The mess resulting from the accident took until February 1954 to clear up!



(*Left*) Harwell's heavy water reactor E.443 (DIDO). At the centre of this diagram is shown the aluminium tank containing heavy water and the fuel elements. For clearness only one fuel element and one control arm are shown. The key to the diagram is given below. (*Right*) The latest photograph showing how DIDO is taking shape.
(*Crown copyright, Ministry of Works photograph.*)

1. Reactor aluminium tank containing heavy water.
2. Level of heavy water.
3. Fuel element.
4. Experimental hole.
5. Graphite reflector.
6. Experimental holes.
7. Water-cooled thermal shield.
8. Experimental hole entering heavy water.
9. Experimental hole entering graphite.
10. Vertical experimental hole.
11. Thermal column of graphite to provide beam of thermal neutrons.
12. One of six control arms.
13. Concrete biological shield.



Top view of DIMPLE, Harwell's first heavy water reactor.

Although the decontamination and dismantling of the reactor, and its reconstruction, provided most valuable knowledge about the amount of work that could be carried on in a highly contaminated area and also resulted in a considerable stepping-up of the power of NRX at a cost of only one-quarter of the price of a new reactor, it is not an experience that anyone wants to repeat, and a number of lessons learned from the Chalk River accident have been incorporated in both the new British heavy water reactors.

As an extra precaution, E.443 will be totally enclosed in a dome-topped cylindrical steel building 70 feet in diameter and 70 feet high that will effectively contain any radioactive materials that may escape due to breakdown of an assembly within the reactor. Similar precautions will, no doubt, be taken with R.E.775.

Heavy water reactors have many advantages in the research field over their graphite counterparts. A very important one is that they require the investment of only about one-tenth of the amount of uranium that would be needed for a graphite-moderated reactor of the same flux. This, of course, means that the heat that will need to be removed will be cut by the same factor. When one of the objects of a reactor is, instead, the generation of as much heat as possible, as for example in a power station, or where the production of the maximum amount of plutonium or isotopes is desirable it follows that the advantages of the heavy water reactor fade. In such cases the larger quantity of uranium will be required anyhow.

Dr. J. V. Dunworth, head of the reactor physics division at Harwell, pointed out when he spoke at the Norwegian Conference on Heavy Water Reactors in August 1954 that there is an intermediate region around 100 megawatts where a heavy water reactor permits quite a small investment of natural uranium, about 10 tons, compared with the 40 tons that would be needed for the same rating in a graphite-moderated system. This may well be of advantage to smaller countries without facilities for fuel enrichment since smaller reactors also mean considerably cheaper shielding. For ship-propulsion they provide the only reasonably compact system unless enriched fuels are available. In Britain, however, the same reduction in size could easily be obtained by use of higher grade fuel. It then becomes a matter of balancing the cost of one against the other. Other factors will also have to be considered, however, and these include the risks of losing very expensive heavy water if leaks take place, especially in a pressurised system.

Heavy water, of course, is water containing a high proportion of molecules in which hydrogen atoms of mass 1 have been replaced by deuterium atoms of mass 2. It occurs in nature as one part in 6000 (about a third of a pound per ton) of all naturally occurring water. The method normally used is the electrolytic one, depending on the fact that when an electric current is passed through water the heavier form of hydrogen tends to be left behind.

A figure of 83 dollars per lb. (equivalent to about £60,000 per ton) has been quoted in American lists while the price from the Norsk Hydro in Norway, from which Britain is drawing supplies to meet its current needs, was, at least until recently, in the region of £75,000 per ton.

A method that has been the subject of a great deal of study recently by scientists and chemical engineers at Harwell is the thermal distillation method which takes advantage of the fact that the boiling-point of heavy water is higher than that of ordinary or "light" water (by 1·42°C). As has already been announced, plans have now been worked out in conjunction with N.Z. engineers and orders given for the construction of a plant that will use geothermal steam from the volcanic areas of the North Island of New Zealand to produce heavy water and electric power. It has been suggested that heavy water from this source might be 40% cheaper than that made by the electrolytic method.

In view of the possibility of an increasing call for heavy water (design studies have already been carried out at Harwell for a large heavy water reactor) this reduction in price may be of great importance.

THE MEANING OF AUTOMATION

Over a thousand production engineers, some electronic engineers and a sprinkling of laymen were attracted to the conference held in June by the Institution of Production Engineers to discuss the Automatic Factory. The size of that audience is a welcome sign that this subject is at last entering the realm of realistic public discussion. Indeed, it would be no discredit to the conference to suggest that its great contribution will be to make clear what the automatic factory does *not* mean, rather than the reverse: *not* robot factories, but automatic processes still under the guidance and ultimate control of factory personnel; *not* human automatons, but more skilled personnel relieved from the monotony of repetitive manual or clerical operations; *not* mass unemployment but the need for retraining and other measures to lubricate the movement of labour to new jobs and new skills.

The conference's outstanding feature was the importance attached by the production engineers, themselves masters of metal and machines, to the effect of automatic production on human beings. The first Industrial Revolution has left, as we know to our cost, a debris of human problems. If, as Sir Walter Puckey asserted, we are already in the grip of a second Industrial Revolution, is it not imperative that managers, technicians and scientists should be aware of the human effects of the machines they introduce? Sir Walter gave the answer to this question in his opening address: "Never before have so many managers and men understood the place of man in industry and in his social structure, the need for closer mutual understanding and the necessity to formalise and improve this through joint consultation, education, training and promotion." The views expressed by other speakers at the conference lent force to this assertion. No doubt the British and French trade unionists present took heart from the insistence with which the technicians expressed their concern for the workers affected by automatic production. For they in

their turn, in a masterly paper by Mr. E. Fletcher of the T.U.C. and in comment in the corridors, made it clear that they would welcome automation, provided that the human and social implications were taken care of, and provided that the workers got their share in higher wages and more leisure. They will no doubt now be waiting to see the proof of this benign attitude in negotiations to come. In this connexion, it is not without interest to note that concern for the worker as a human being has found practical expression in the French Renault Works, itself a pioneer in the field of automatic production. This company has a team of sociologists and psychologists who, in close collaboration with the production and methods engineers, study each production job to see what physical and psychological strains are put on the individual. We in this country have surely something to learn from this.

Are the new techniques really revolutionary? Or are we making a song and dance about a fancy new word, automation, for a straightforward evolution in production technology? The answer would seem to be a bit of both. Transfer machines involving the automatic transfer of the work-piece into and out of machine tools, such as those at Ford's, Austin's and the Russian piston factory, have been dramatised out of all proportion to their importance in the total movement towards automatic production. They are a straightforward evolution in mass production techniques of metal working. More radical changes in the concept of production can be expected from the intensive and integral application of control engineering and communication engineering to complete production processes. Lord Halsbury further clarified the picture by emphasising that the prospect of the automatic factory is not due to a single, clear cause. He listed four component factors: transfer machining, control engineering, communication engineering and mechanical assembly.

But despite the diversity and multiplicity of the developments discussed at Margate, the rough anatomy of the automatic factory did emerge, even if only vaguely, from the discussions. A first point is indisputable: a wide range of individual factory operations can be automatically controlled by self-correcting "feed-back" controls. Examples quoted in the discussions ranged from the control of ball-bearing dimensions to that of the thickness of sheet steel in a continuous rolling mill; from the control of dough-weight in bakeries to the maintenance of correct pressures and temperatures in complex chemical processes. But applications appear to be limited to the control of comparatively simple production operations such as counting and the control of weight, thickness, width, tension, speed, and so on.

The bottlenecks in the spread of automatic control are the more complex tasks such as the assembly of components and the cutting and shaping of complex metal shapes by machine tools, both of which would be needed before automation could become widespread in manufacturing industry.

There was little evidence of any real advance in the automation of assembly operations. However, a paper from the Ferranti organisation revealed that considerable development work has been carried out on the automatic control of machine tools by electronic computers, and it seems likely that such automatic machine tools will soon become a practical proposition.

Looking beyond the control of individual operations or machine tools, the next step in the progress towards the automatic factory would be to provide the individual automatic control mechanisms with a master-controller, a "brain" to co-ordinate and control the individual limbs of the process according to the overall production plan. This "brain" will undoubtedly be the electronic digital computer. It is at this stage that we might legitimately begin to talk of the "automatic factory". Although none exists at the present time, and although the economics of such a step have yet to be proved, the conference envisaged developments in this direction for process industries such as chemicals, petroleum and sugar-beet refining. The final stage—the Mecca of the automation enthusiasts—is the use of the electronic digital computer not only as the master controller of the individual process controls, but also as the administrative and management "brain", establishing a production plan in the light of orders, sales forecasts and stocks, and controlling the production process so that the plan is fulfilled. The conference rightly relegated such exciting prospects to the background, and concentrated on the more modest aspirations of automation in the office: as a tool for the more rapid execution of clerical routines such as the preparation of payrolls and stores accounting, and as a means for management to have more, and more rapid, information about its operations. The electronic computer promises to have far-reaching applications in this direction. J. Lyons & Co. Ltd. have already shown the way with LEO, and other organisations are known to be following on with the smaller computers now coming on to the market.

In the last analysis the vital question is, how fast is industry going to take up these new techniques for automatic production? It was on this point that the conference threw least light. Scepticism concerning the economic advantages of the new techniques could be seen lurking in the minds of many managers and production engineers, fortifying natural professional conservatism towards "these new-fangled electronic gadgets". One noted the suggestion that industry should take the plunge before the last technical and economic "i" has been dotted by those responsible for the research and development. But the leap in the dark is only likely to be taken by those with a confident understanding of the technical basis of the new techniques. In fact, the abiding impression left by the conference was that the rate of progress in this field is likely to be limited, not so much by trade union resistance and the like, as by the dearth of managers and production engineers able to introduce and operate automatic plants effectively. Something in the nature of an educational campaign is called for, not only to create the new technical cadres, but also to give the existing generation of managers and production engineers a foothold in the new production techniques.

RADIOACTIVE TAGGING OF SMALL MAMMALS

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The ecologist is concerned with the relationship between the animal and its environment. Nearly all of an animal's activities, such as feeding, mating, and looking after the young, involve movements of some kind, and for this reason the study of movements is of prime importance in animal ecology. It has always been difficult to obtain reliable information about the movements of small mammals, because of their retiring habits and the fact that they are often most active at night.

In a population of small mammals, each individual normally feeds and moves about within a restricted area. In the case of British mouse-like rodents this area covers up to a few hundred square yards and is known as the individual's "home range" or simply "range". The home range varies in size at different seasons and is usually larger for males than for females. The home ranges of neighbouring animals often overlap, this being one of the ways in which home ranges differ from "territories", which are usually occupied exclusively by one or a pair of animals.

The usual method of attempting to determine the situation and extent of an animal's home range is to catch it alive in harmless box-traps on a number of occasions, and plot the situations in which it is caught on a map of the area. During the last two or three decades there have been considerable advances in the design and technique of using mass-produced box-traps, side by side with the development of marking methods utilising metal ear-tags and leg-rings. The live-trapping method has, however, a number of disadvantages. In the first place, it is often difficult to trap any particular animal enough times to get a clear picture of its range. Also, repeated trapping probably has physiological and psychological effects on the animal which influence its movements. We suspect, for example, that an animal may be unusually active after being confined in a trap for some hours. An American worker, studying the movements of a small rodent by means of live-trapping, found that there was a clear correlation between the size of the apparent home range and the distance between the traps, the range being smallest when the traps were closest together.

It seemed likely that a direct method, such as labelling the animal with radioactive material and tracing it with a Geiger counter might give a more accurate picture of its home range. The method had already been used by a British ecologist for tracing small movements of beetles in soil. A technique has now been devised which consists of labelling a small mammal such as a mouse or vole with 80–100 microcuries (approximately 10 milligrams.) of radioactive cobalt so that its movements can be traced with a portable Geiger-Müller counter unit, the tube being mounted at the end of a long handle.

The method was first applied to a study of the short-tailed field vole (*Microtus agrestis*). The radioactive cobalt was used in the form of wire, 1 millimetre in diameter. This was cut into short lengths which were cemented into small brass capsules. The capsules were soldered to numbered nickel leg-rings, which were fastened about the voles' hind legs using specially modified pliers. The Geiger-Müller tube used is a commercial type with a plateau in the vicinity of 400 volts, which can be maintained by a series of small dry cells. The tube is mounted in a light metal casing at the end of a jointed 8-foot bamboo pole, and connected by a cable with a simple two-stage amplifier which drives a pair of headphones (Fig. 1). The long handle ensures that the animal will not be disturbed by the observer's movements.

The observer walks slowly forwards sweeping the probe from side to side in wide arcs, listening for a perceptible increase over the background count, which is about 80 per minute. When a fast count is detected the probe is swung backwards and forwards over the vegetation until the source has been located precisely. It might be supposed that a more reliable method of locating the animal might be to use a calibrated dial instead of headphones. This proves to be quite impracticable in the field, however, as the observer's eyes are fully occupied in ensuring that the probe is passed over every portion of the area being searched, in disciplining the observer's movements, and in avoiding obstacles such as trees and ditches. The ears are free to concentrate on the headphone sounds, and with practice one develops a good degree of co-ordination; the probe is swept to and fro, brought back over a suspected area in response to a sudden increase, and moved on again almost without conscious thought.

As it was not possible to distinguish between two individuals with radioactive rings, it was desirable to avoid labelling animals with home ranges that adjoined or overlapped. The usual procedure was to set between fifty and a hundred box-traps the day before the animals were to be ringed. Next day the traps were inspected and the voles examined, any other rodents or shrews which had been caught being released. This particular study was primarily concerned with female voles, and so the males were also released. Females which had been trapped a good distance apart, perhaps 100 yards, were selected, and radioactive rings placed on their legs. They were set free and left for twenty-four hours to settle down. Then the area was searched, beginning at the points of release and moving in a series of concentric circles. It often took an hour or more to find the animals on the first occasion, but it became easier, of course, as the extent of their ranges became known. The area of grassland was marked out with wooden stakes in a grid pattern, and these were used as points of reference in transferring the information to a map of the area.

An estimate of an animal's home range may be obtained by drawing a line to join the outside points at which it was located and measuring the enclosed area. One can test whether this area does in fact

FIGURE 1.
Searching for tagged moles with a Geiger-Müller tube.
(*Photo by Dr. Peter Crowcroft.*)

represent the true home range by proceeding to locate the animal several more times. If the new records consistently fall within the perimeter already drawn, it is reasonably certain that the map is reliable. It was found that the outer limits of a female vole's home range were accurately determined by locating her about twenty times spread over several days. The results were checked against live-trapping evidence for the same animals. The tagged individuals were always caught within their ranges as determined with the Geiger counter.

Thus this method, applied to the vole, has enabled some interesting checks to be made upon the live-trapping method, but perhaps more important is its usefulness in studying the movements of the mole (*Talpa europaea*), a fossorial mammal for which no satisfactory live-trap has yet been invented. The legs of this animal are not suitable for ringing; the fore-limbs are enlarged organs specialised for digging, and the hind-limbs are short and stumpy, lacking the necessary narrow shank and enlarged ankle. Fortunately, however, the tail of the mole is spindle-shaped, and a metal ring can be closed loosely about its narrow base. In this position a light metal ring does not interfere with the mole's normal activities. The animal is caught for marking by turning it out of the soil with a spade, or, if it can be found working near the surface in moist loose earth, by pressing the heel into its tunnel and digging it out with the bare hands. After being released, bearing the radioactive ring, it is located by sweeping the area with the long-handled probe, as with the vole. The soil has a considerable dampening effect on the radiation but this is compensated for by the fact that in closely grazed pasture or freshly ploughed arable fields the tube can be brought very near to the soil surface. If the mole is working near the surface detection is not difficult, for the headphone "clicks" merge into a continuous stream when the probe is about a foot from the animal, and an increase is perceptible 4 feet away. On the other hand, when the mole is digging or resting in a tunnel 18 inches deep, its presence is revealed only by a slight increase in count over an area several feet in diameter.

The fact that a mole's movements are confined to a system of more or less permanent tunnels means that a much more intimate picture of its daily movements can be built up than is the case with the vole living in dense grass. The observer is helped, too, by the heaps of earth thrown on to the surface by the mole, as these give some indication of the configuration of the underlying tunnels. The limitation of movement to a relatively few fixed pathways is also of great use in proceeding to the next stage of the investigation, which is not merely to note the animal's position on a number of occasions, but to actually follow it about continuously for long periods. Records are kept of *where* it moves and *when* it habitually does so. In favourable habitats, such as the permanent pasture shown in Fig. 1, it is possible to maintain "contact" with a mole during an entire bout of activity, to follow it back to its nest, and by checking every few minutes, to establish the time at which it becomes active again. This leads to the establishment of the mole's "activity pattern", or the time framework in which it gets its food and expends the energy derived from it.

The radioactive technique is also proving useful in tackling one of the most difficult problems in small mammal ecology, the study of the growth, survival and dispersal of the young. In the first place, nests are extremely hard to find: those of the short-tailed field vole, for instance, are always well concealed in long grass, and those of the mole are subterranean, often lying 18 inches below ground with no indication on the surface of their presence. In the work on the vole carried out a few years ago, a number of nests were found by putting radioactive rings on visibly pregnant

females, and later examining the places where they were spending most of their time. Each time a nest was found, the young were weighed on a spring balance. The young voles weighed about 2 grams at birth, and 6–7 grams a fortnight later when they were weaned. It was not possible to get continuous records of the growth of any one litter for not only did the mother frequently move them, but as they grew older she took to spending less and less time in the nest, so that locating her seldom led to its discovery.

With moles greater disturbance of the nest is inevitable as it must be dug out of the ground, thus destroying the runways and modifying the shape of the nest chamber. Fortunately, however, the female's ability to move her young seems to be limited, and the new nest is seldom more than a few feet away. The method adopted in current work is to delay digging out the young until the date on which it is estimated that they will be large enough to wear radioactive rings. The estimate of the age of the young has to be based on the previous examination of the pregnant female. The timing of this first disturbance is rather critical, for if the young are too small they cannot be ringed, and if too large they will leave and take refuge in the tunnel-system before the nest is exposed. If one manages to get the young moles at an age of about two weeks, a radioactive ring is temporarily attached to the hind limb as the tail is not yet sufficiently swollen. The nest can then be repeatedly located independently of the mother. Later when the young are moving about outside the nest they are captured—a relatively easy procedure as their exact position in the soil can be determined—and the ring transferred to the base of the tail.

It is in the current work on the mole, hitherto the subject of much conjecture but very little objective study, that the method of radioactive labelling as applied to small mammals is likely to be of the greatest usefulness. For obvious reasons, radioactive tags cannot be distributed among a population of voles which is likely to be subject to a high mortality rate due to predation by owls, weasels and foxes, without the possibility that the tags may be carried some distance by a predator before being dropped. The limited range of movement of the mole, however, together with its relative freedom from predation, means that a number of interesting problems can be undertaken with little likelihood that radioactive material will be lost. During the present work, in fact, every ring has been recovered and re-used a number of times.

READING LIST

Further details about these investigations can be found in the three following papers by Dr. Godfrey:

"Tracing field voles (*Microtus agrestis*) with a Geiger-Müller counter." *Ecology*, 1954, vol. 35, pp. 5–10.

"A technique for finding *Microtus* nests." *J. Mammal.* 1954, vol. 34, pp. 503–5.

"A field study of the activity of the mole (*Talpa europaea* L.)." *Ecology* (in press).

CHARLES BLACHFORD MANSFIELD (1819–55)

E. R. WARD, B.Sc., Ph.D., A.R.I.C.

On February 17, 1855, in a room in St. John's Wood, London, a chemist and his assistant were engaged in distilling coal-tar naphtha to obtain specimens of liquid aromatic hydrocarbons for the Paris Exhibition of that year. Suddenly the still ignited, and with thought only for the safety of others the chemist endeavoured to move the blazing still into the street. In so doing he was severely burnt and injured. Nine days later he died in the Middlesex Hospital. So perished Charles Mansfield in a manner characteristic of his whole life; a life devoted to the progress of science and the amelioration of the lot of his fellow men. His death at the age of thirty-five was a serious loss to science, since many of his contemporaries believed that so outstanding was his talent that he would succeed Michael Faraday at the Royal Institution.

Mansfield was born in Rowner, Hants, the eldest son of a wealthy, aristocratic and well-connected parson. After following the usual course in classics at Winchester (1831–6), where his career was not a distinguished one, though he was a Scholar, he spent two years with a private tutor at Castle Ashby, Northamptonshire. It was here that he became acquainted with the family of the second Marquess of Northampton, then the President of the Royal Society, who encouraged him in his scientific studies, which led him eventually (in 1846) to enrol as a student of the newly founded Royal College of Chemistry (of which the Marquess was a patron). Previously (in 1839, to be exact) he had become a Freeman Scholar of Clare College, Cambridge, but he did not graduate as a B.A. till 1846, being incapacitated for a long period with a spinal complaint.

He also undertook some medical training at St. George's Hospital, London, whilst he was a Cambridge undergraduate. In March 1846 he commenced studies at the Royal College of Chemistry where the Professor was the renowned A. W. Hoffman, a product of Liebig's famous school at Giessen. After about six months' training he began an investigation of the hydrocarbons in coal-tar.

In 1825 Faraday had isolated benzene from a compressed illuminating gas that was manufactured by the pyrolysis of whale or cod oil. Twenty years later Hoffman detected its presence in coal-tar. Although something was known of the acidic and basic components

of coal-tar, almost nothing was known about the neutral hydrocarbons contained in it when Mansfield started his investigations. Using primitive apparatus in an improvised laboratory, Mansfield worked with such logical thoroughness and care at the repeated fractional distillation of coal-tar naphtha that by November 11, 1847, he was able to take out a provisional patent relating to his work (B.P. 11,960, Old Law), which was finally sealed on May 8, 1848. It is impossible here to deal in detail with that extremely long and involved patent, which like most of Mansfield's work was brimming over with ideas. It not only described methods for the large-scale isolation of benzene, toluene, and other compounds, but it also dealt with numerous other matters including the production of odoriferous oils by nitration, the manufacture of oils for illumination, and apparatus for their volatilisation and combustion. The last-mentioned usage is particularly interesting since Mansfield visualised that the main application of benzene and related products would be as illuminating agents and he devoted much time to publicising this possibility (e.g. his paper published in the *Proceedings of the Institution of Civil Engineers*, 1849, pp. 207–32).

Mansfield also considered the application of his methods of distillation to the fractionation of other materials such as wood tar and petroleum. The distillation methods he devised were novel in many ways; hence the statement in Thorpe's *Dictionary of Applied Chemistry* (1921 edition) that "Mansfield laid the whole foundations of the benzene industry, and his processes, with scarcely a change, are in use to this day". He also suggested that the rectification methods used in alcohol manufacture, based on the use of Coffey's still would be applicable to coal-tar naphtha, and this suggestion was taken up successfully by Coupier in 1863.

Still later, in a paper to the Chemical Society (*Journal of the Chemical Society*, 1849, vol. 1, pp. 244–68), he drew attention to the urgent need to exploit coal-tar for commercial purposes. Mansfield's greatest contribution in this field was the devising of methods for making available pure aromatic hydrocarbons, and whilst in his lifetime their use was confined to illuminants and rubber solvents, Perkin's discovery of mauveine in 1856 led to immediate and ever-increasing demands for such materials. It is clear that the progress of Colour Chemistry, and for that matter of Organic Chemistry itself, would have been severely delayed without Mansfield's work.

Mansfield also drew attention to the possible use of benzene as an anaesthetic, and of phenolic bodies as antiseptics. (That was twenty years before Lister's work, who was apparently ignorant of both Mansfield's suggestion and the investigations of the Prussian chemist Lemaire.)

C. B. MANSFIELD.

Mansfield was a man of prolific interests. He wrote a treatise on the constitution of salts, and a work on *Aerial Navigation*. He made a pioneer voyage to Paraguay, which was followed by a detailed account of the country and the presentation of a paper on the language of the Payagwa Indians to the Philological Society. He had a life-long interest in nature study, and wished to formulate a comprehensive philosophy of life and nature derived from Christian principles. His principles he put into practice by his pioneering work (along with men like Charles Kingsley) in such fields as "Christian Socialism", "Trade Unionism", "Co-operative Trading" and "Working Class Education". Mansfield also worked with Kingsley in the struggle for sanitary reform in the new industrial towns, and was not above driving a water-cart in Bermondsey.

He was a noble-looking person, a brilliant conversationalist, fascinating all who met him, and inspiring in them a deep love and devotion. He has been aptly described as "a great soul stirred by mighty conceptions and the love of mankind". His brief life, with its diverse achievements, is an inspiration to all who would serve science for the benefit of mankind.

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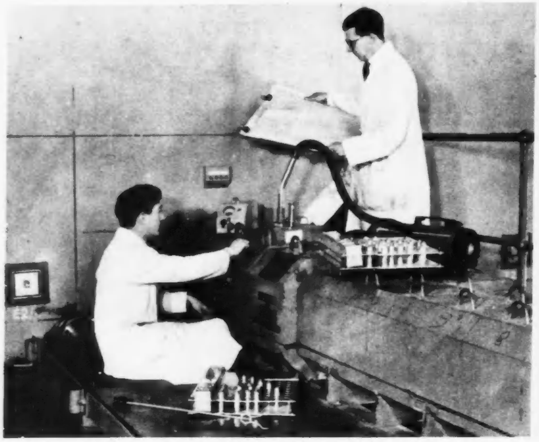

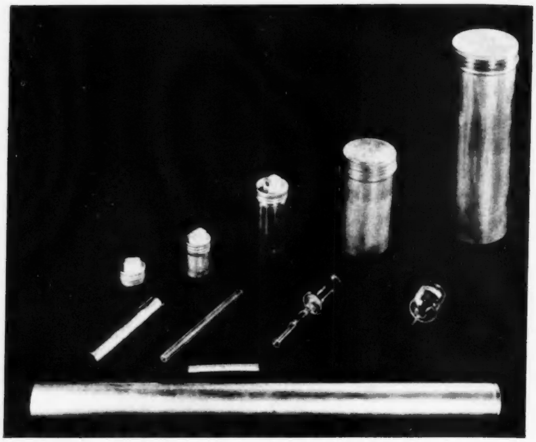

FIG. 1*a*. (*left*) Loading samples into the BEPO pile at Harwell for irradiation. FIG. 1*b*. (*right*) Isotope containers used for pile irradiation.

RADIO-ISOTOPES IN THE SERVICE OF INDUSTRY

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The recently published programme for the development of atomic power in Britain marks the opening of a new era, and the immense new source of power will undoubtedly have far-reaching effects on our industries and our national economy. Its results will take time to be felt, however, and in keeping our eyes on this ultimate goal, it would be well not to lose sight of a less spectacular by-product of the atomic age—artificial radioactivity.

Radioactive materials are now produced in large quantities by the exposure of normal everyday chemicals, such as common salt, to the action of penetrating neutrons inside an atomic pile. Britain is the largest producer and exporter of these radio-isotopes in the world and their sales contribute in a small degree towards the costs of further nuclear research. The cost of these substances is negligible, however, compared with the great economies which their use has already effected in industrial processes and with the value of new developments which radioactive techniques and process control have made possible.

PROPERTIES AND PRODUCTION

Before discussing the ways in which radio-isotopes can be used, let us consider briefly what they are and how they can be produced in an atomic pile.

All elements are believed to consist of atoms, which contain a heavy central nucleus carrying a positive electric charge and a number of electrons revolving around it. These carry between them a total negative charge sufficient to neutralise the charge on the nucleus, and the number of electrons, set by the charge on the nucleus, determines the element to which the atom belongs.

The nucleus itself is believed to consist of positively charged protons and uncharged neutrons, held together in a stable arrangement by nuclear forces. The number of protons determines the nuclear charge and hence the chemical nature of the atom. The total number of protons plus neutrons determines the atomic weight. Isotopes of an element are atoms containing equal numbers of protons in their nuclei, but different numbers of neutrons. Hence they have the same chemical properties but different atomic weights.

Now a nucleus which contains too many or too few neutrons is not stable, and it is liable at any time to change its structure to a more stable arrangement by emitting a particle or particles. This is the essence of radioactivity, and the manufacture of radio-isotopes consists in disturbing the stability of atomic nuclei. When a sample of cobalt, for example, is placed in an atomic pile, the uncharged neutrons, which are present in great abundance in the pile, are able to penetrate some of the cobalt nuclei and some of them are captured. Those cobalt nuclei which have gained an extra neutron are now unstable: their atomic weight has increased from 59 to 60 and they will eventually regain stability by emitting in rapid succession a high-speed electron (or beta particle) and two penetrating gamma rays.

This last process is called disintegration, and goes on at a decreasing rate until all the atoms in the sample have regained stability. The time taken for the number of radioactive atoms (and therefore the gross disintegration rate) to fall to half of the original figure is about 5·2 years. This is known as the half-life of cobalt-60. After the elapse of a period equal to two half-lives the gross disintegration rate has fallen to a quarter. The

half-lives of radio-isotopes range from fractions of a microsecond to millions of years. Those whose half-lives are between a few hours and a few years are the most useful for industrial purposes.

Fig. 1 shows arrangements for loading materials into the Harwell pile for neutron irradiation.* The inactive materials are enclosed in aluminium cans which were designed to be carried into the middle of the pile in sliding graphite blocks. After suitable periods the samples, now radioactive, are extracted and dispatched, sometimes after chemical processing.

Another potent source of radio-isotopes is in the uranium fuel rods. The operation of the pile consists in the breaking up or "fission" of uranium atoms into smaller ones, with release of energy. These smaller, lighter atoms, which have been described as the "ashes" of atomic energy, accumulate in the fuel rods, which therefore have to be removed periodically and re-purified. The fission products thus removed are mostly radioactive and are themselves separated and purified for use as radio-isotopes.

APPLICATION OF IONISATION

The radiations which are emitted in the disintegration of radioactive substances produce ionisation in the materials through which they pass—that is, they dislodge electrons from atoms, leaving the atoms positively charged. Gases are thus made electrically conducting, for the free electrons will move in one direction in an electric field, whilst the residual positive ions move in the opposite direction, and these movements constitute an electric current.

This fact is used in the *radioactive static eliminator*, used to remove the surface electric charges which are produced by friction on insulating surfaces such as plastic sheets, wrapping materials or threads in a loom. Left to themselves, these charges can produce chaos in automatic machines by causing the charged materials to fly apart or stick to metal surfaces, or (in weaving) can attract dust particles which mar the finished cloth.

A radioactive source of beta particles, such as thallium-204 mounted in an earthed metal container at a distance from the charged surface, produces ionisation in the intervening air (see Fig. 2), enabling it to conduct away the unwanted electric charges.

Radioactive gases inserted into gas-discharge tubes have also been found beneficial in reducing the striking time of the tubes. This is because they ionise the gas in the tubes, thus providing a continuous small supply of the free electrons necessary to initiate a discharge.

These are the main ways at present in which the radiations themselves are used to do an industrial job. In the applications which follow, the radiations are used only as a means of measurement: it is in this way that the greatest use of radio-isotopes is made.

RADIOGRAPHY

Techniques of X-radiography are well established for the non-destructive testing of welds and castings, and

*The arrangement has recently been modified to use an endless belt for insertion of samples into the pile.

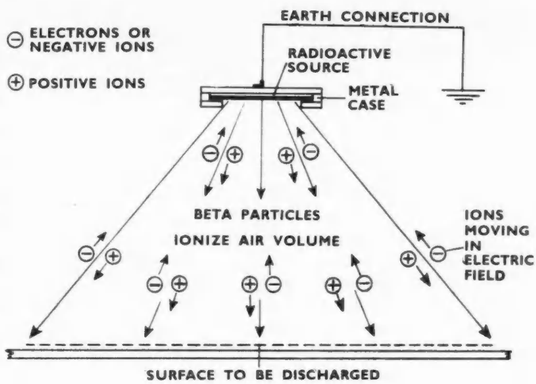


FIG. 2. Radioactive static eliminator.

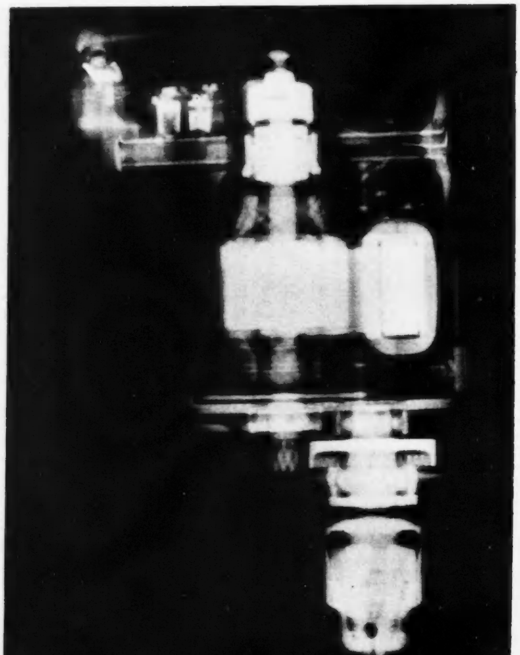
for decades the gamma rays from radium have been used for the radiography of thick samples requiring very penetrating radiations. Unfortunately, the cost of radium is high, and so is the cost of installation and maintenance of a high-voltage X-ray machine. By contrast cobalt-60 is cheap, and the gamma rays from this isotope are equivalent in penetration to those from a 2-million-volt X-ray machine. Many foundries unwilling to maintain expensive X-ray equipment are now testing their products by convenient overnight exposures in which the castings for test are arranged with their X-ray films around a central cobalt-60 source.

The gamma rays from this isotope are suitable for radiographs of steel thicknesses from 1 to 6 inches, and samples up to 10 inches thick have been tested in this way. For smaller thicknesses, caesium-137 (a fission product with a half-life of 33 years) is suitable for $\frac{1}{2}$–2 inches of steel; thulium-170, emitting radiations roughly equivalent to a 200-kilovolt X-ray set, is convenient for small thicknesses and light alloy radiography. Figs. 3 and 4 show some typical radiographs taken with these two radio-isotopes.

One feature of gamma radiography is its flexibility. Radiographic sources are in the form of small cylinders down to 2 millimetres in diameter and length and, with suitable handling precautions, they can be mounted in positions quite inaccessible to X-ray machines. For example, a uniform radiograph of a pipe weld can be obtained by mounting a source on the axis of the pipe and wrapping an X-ray film around the outside of the weld. This manœuvrability is making the use of radio-isotopes increasingly popular for radiography, and in some problems enables their successful use where other methods fail.

THICKNESS GAUGES

The casting of shadows on an X-ray film in radiography is of course a means of recording the absorption of X-rays of gamma rays in a medium. Similarly the absorption of gamma rays or beta particles in a homogeneous medium can be used as a measure of its thickness. Fig. 5 shows *a non-contacting thickness*



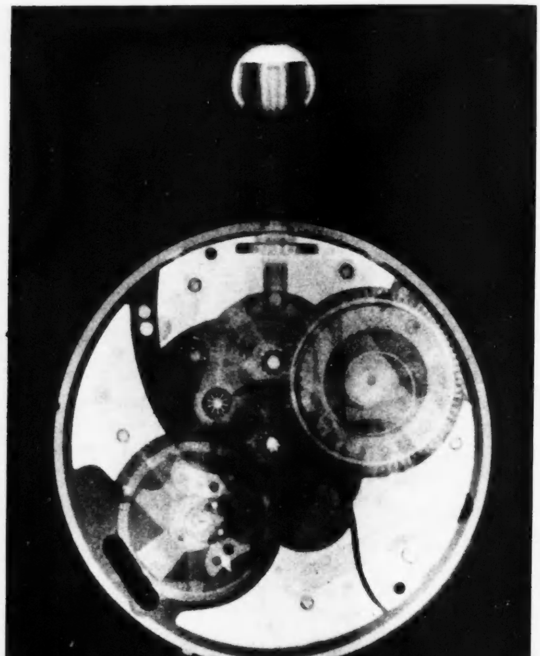


FIG. 3. (*left*) Radiograph of electric drill, taken with iridium 192. FIG. 4. (*right*) Radiograph of stop-watch, taken with thulium 170.

gauge of the type which can be used to monitor continuously the thickness of paper, plastics and thin metal strip.

The sheet of material to be measured passes between a radioactive source of beta particles and an ionisation chamber detector, which records a current proportional to the rate at which beta particles penetrate the sheet. A sheet of standard thickness is placed between a second source and ionisation chamber, and the currents from the two detectors are arranged to oppose one another. The difference current is displayed on a meter which is calibrated to show the departures of the measured sheet from the standard thickness.

Various thickness gauges of this kind are commercially available, using beta particle sources for small thicknesses up to that which corresponds to a weight of 10 kilograms per square metre (just over $\frac{1}{8}$ inch of aluminium). Gamma ray sources are used for greater thicknesses, up to a few inches of steel. Some gauges are arranged to operate electronic servo-mechanisms which control the thickness of the product and maintain it between pre-set limits automatically.

Other radioactive thickness gauges, by measuring the beta radiations scattered from a surface, are used to measure the thickness of paint or plating on a base material. Yet another type of gauge, in which scattered gamma rays are measured, records the wall thickness of a steel pipe, or enclosed tank (up to 1 inch thick), without access to the inside.

In an interesting variant of the transmission gauge described above, a radioactive source and detector are used to detect empty or underfilled packages on a conveyor belt in a factory. In this device the source and detector are mounted at a critical level on opposite sides of the conveyor belt (see Fig. 6). The source is chosen so that its radiations can penetrate the walls of an empty package to the detector, but are heavily absorbed when the contents are above the critical level. A beam of light and a photo-cell are used to locate the packages and an automatic device operated by the package monitor ejects the empty or underfilled packages.

RADIOACTIVE TRACERS

By far the most versatile research tool introduced by the use of radio-isotopes is the radioactive tracer technique. This has already revolutionised medical and biochemical research in the study of metabolic processes, and is finding increasing applications in pure and applied science.

A radioactive source can be detected and measured by virtue of the radiations which it emits: for a particular isotope, the rate of emission is proportional always to the number of radioactive nuclei present in a sample. Since these have the same chemical properties as ordinary stable isotopes of the same element, a mixture of radioactive and stable atoms of an element will maintain the same proportions whatever chemical

changes it may undergo. Just as the behaviour of a large flock of birds can be followed by "ringing" the legs of a proportion of them, so the fate of a chemical sample can be studied if a proportion of its atoms are radioactive.

Radiations are generally detected with Geiger counters, or with the more recently developed scintillation counters, the latter being specially suitable for the detection of gamma rays and capable of recording up to 100,000 or more gamma radiations per second. The detectors feed electrical pulses, corresponding to the arrival of radiations, into electronic recording systems which either record the total number of radiations arriving in a period of time or indicate their rate of arrival on a meter.

Tracer applications are many and varied. Complex chemical processes can be followed simply, often from outside the containing vessels, by the addition of radioactively labelled elements or compounds. The wear of piston rings, bearings and journals in test engines can be measured, rapidly and without dismantling, by using radioactivated components and measuring the activity of wear debris carried by the lubricating oil. Silt movements on the bed of a river estuary can be followed for miles and over a period of weeks by using glass powder (containing scandium-46) as a radioactive sand. Vapour pressures too low to be detected by orthodox methods can be measured by using a radioactive liquid or solid and measuring the activity in the vapour.

Industrial mixing processes of all kinds can be checked as to their efficiency by the addition of minute quantities of radioactive material. A tenth of a gram of common salt can be irradiated for half a day to contain enough sodium-24 activity to label a ton of cattle food. After mixing, measurements of the activity of the products, either on a conveyor belt or in individual sacks, indicate by their degree of uniformity the efficiency of mixing obtained. Sodium-24, by virtue of its short half-life of 15 hours, is particularly suitable for tests of foodstuffs, because its radioactivity decays in a few days to a negligible and completely harmless level.

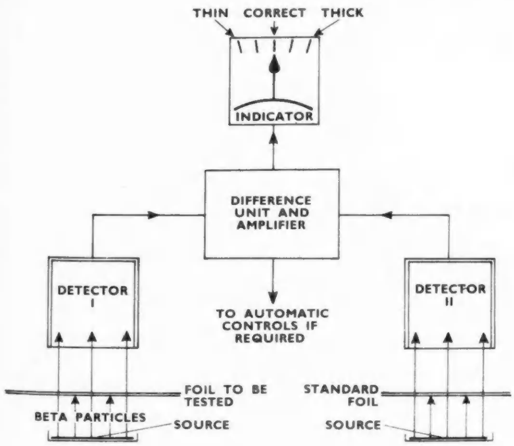


FIG. 5. β-particle thickness gauge.

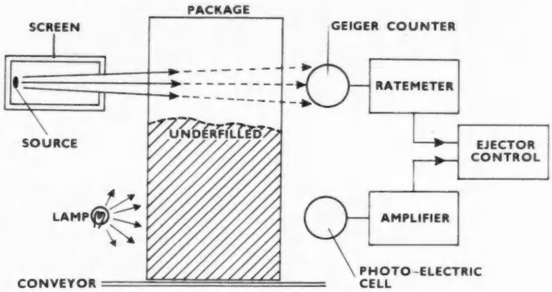


FIG. 6. Package Monitor. The beam of radiations from the source penetrate to the counter when the package is underfilled, but are absorbed by the contents of a full package. Light rays are cut off from the photo-electric cell whenever a package is in position.

LEAK DETECTION

For this reason, too, radioactive sodium has also been chosen for the location of leaking joints in buried, freshly laid water mains. A radioactive solution is introduced into the main and raised to the operating pressure. After a suitable period to allow some of it to penetrate any leaks into the surrounding soil, the solution is replaced with clear water and the leaking joints are found by detecting the residual activity in the soil with a counter inside a metal probe. The radioactivity is allowed to decay to a negligible level before the main is put into service, but it is interesting to note that the original radioactive solution need contain no more than one-tenth of that which is stated by international authorities to be safe for human consumption. In a recent development of this method for use in long oil pipelines, leaks are detected from inside the pipeline by a self-contained detector and wire recorder which are towed along with the flowing oil. When the detector unit is removed at the end of several miles of pipeline, the wire recorder is "played back" and registers the position of any leaks in the section under test.

Some applications of radioactive tracers to metallurgical problems illustrate the use of photographic films as detectors. When an alloy is made up with one of its constituents radioactive, the distribution of this constituent can be studied in detail by laying a polished section on a photographic film. Radiations from the labelled constituent then produce local exposure of the film which, when developed, presents a picture, or autoradiograph, of its distribution. The resolution of the picture varies with the thickness of the sample if the radiations from the tracer are penetrating, but under good conditions, and when the tracer emits only low-energy beta particles, resolutions from 30 to 50 microns are easily obtainable.

Fig. 7 is an enlargement of an autoradiograph taken in an investigation of paper manufacture and shows the

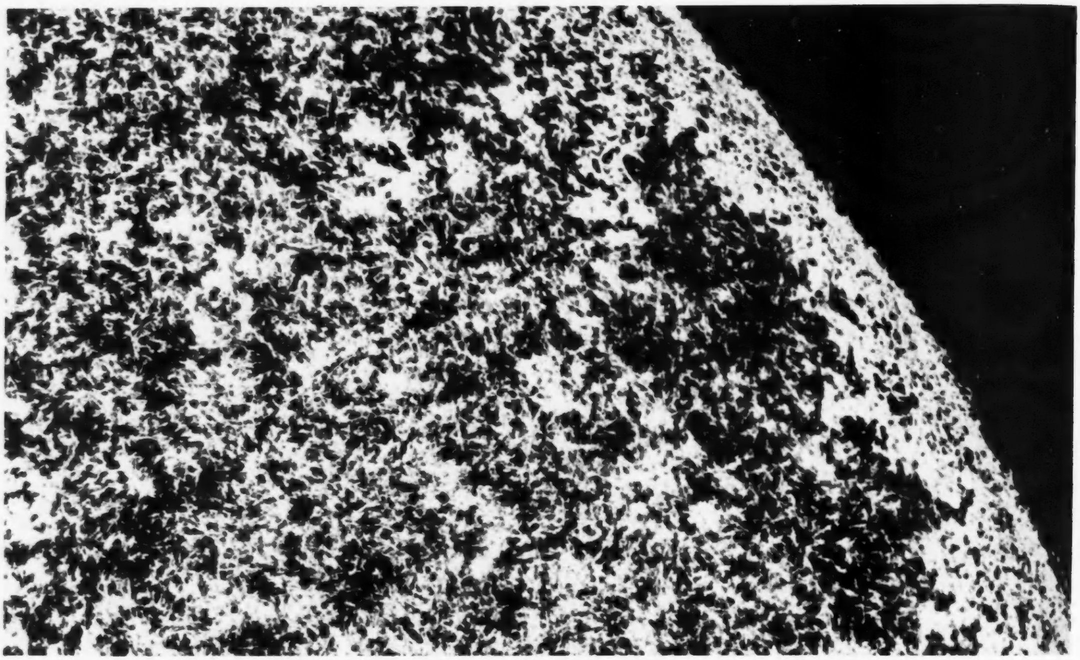


FIG. 7. Autoradiograph of resin in paper, using sulphur-35; magnification, ×5. Concentrations of resin appear white in the picture.

distribution of resin, labelled with sulphur-35, on the surface of a sheet of paper. The figure is a positive print, so that radioactive areas appear white. Individual fibres to which the resin has adhered can be distinguished.

SERVICES AND SUPPLY

The possible applications of radio-isotopes are almost unlimited in number, and only a few of the more established techniques have been described above. All of the instruments mentioned are available commercially, together with many others for the detection and measurement of radiations.

There are few industries to which the use of radioactive materials cannot be of assistance, either in research or in process control, and it is hoped that this brief survey will stimulate the reader to consider new uses for these techniques.

(Advice on the supply and use of radio-isotopes can be obtained from: The Isotope Division, A.E.R.E., Harwell, near Didcot, Berks, whose experts will be pleased to advise on individual problems.—EDITOR, DISCOVERY.)

The photos reproduced as Figs. 3–4 were taken by R. West of the Isotope Division, A.E.R.E. Fig. 7 is reproduced by courtesy of Dr. F. L. Hudson, B.I.P. Chemicals Ltd.; a report of this investigation will be published by the Technical Association of the Pulp and Paper Industry.

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ZIRCONIUM AND THE ATOMIC POWER AGE

T. I. WILLIAMS, D.Phil., F.R.I.C.

The requirements of the present vast atomic energy projects, both civil and military, have led to the development of many new constructional materials. Many of them will certainly find other uses, though these might not in themselves have justified the high cost of research and development. Among these materials is the metal zirconium, whose production on a substantial scale has been officially described as one of the major tasks in the construction of the atomic-powered submarine *Nautilus*. Interest in the metal in this connexion arose from the fact that it has properties making it particularly suitable as a "canning" material for the blocks of almost pure uranium 235 which are used as fuel for the water-moderated reactor which forms the submarine's primary power unit. This power unit is used to raise steam in boilers which provide steam to drive the vessel's propellers. Zirconium's resistance to corrosion, its high melting-point (about 1845°C) and its ability to absorb slow neutrons make it a particularly suitable material for use within high-temperature reactors of this kind.

Although interest in zirconium has thus been aroused by one of the most recent developments in modern science, the metal, in the form of certain ores, was probably well known to the ancients. In the Apocalypse jacinth (or hyacinth)—a red or orange variety of zircon —is named as one of the twelve precious stones which garnished the city wall; this mineral is a silicate of zirconium. It was also, though possibly in this context amber was meant, listed as one of the embellishments of the breastplates of the Horsemen. The court dress of Honorius was described as sparkling with amethysts and hyacinths, though the disasters which beset the Roman Empire under his rule give no colour to the ancient belief that zircon protects its wearers from ill-fortune. Zircons also occur in blue and green forms—known as jargoons—as well as in a colourless form. It has long been known that coloured zircons can be made colourless by heating, enabling unscrupulous traders to pass them off as diamonds.

Although various compounds of zirconium were thus familiar from ancient times, knowledge of their composition has been acquired only comparatively recently. In 1789 Klaproth discovered that zircon from Ceylon contained an "earth" different from any then known, and which he named *Zirkonerde*. Vauquelin investigated this earth—the oxide of the metal—in some detail, and prepared various compounds of zirconium, but the metal itself eluded him. Humphry Davy unsuccessfully tried to decompose the oxide electrolytically in 1808. Not until 1824 was the metal itself obtained, and then only in an impure form, by Berzelius. Berzelius' method was to heat potassium fluoride and potassium zirconium fluoride in an iron tube; by this method the metal is obtained as a black powder resembling charcoal. Later workers—including Weiss, Neumann, Wedekind, Troost, Moissan—obtained progressively purer samples, but the great avidity of zirconium for oxygen presented a major problem; even traces of impurity make the metal very brittle and difficult to work. Not until 1914 was really pure zirconium obtained. Lely and Hamburger, at Eindhoven, prepared it in a malleable form by the action of sodium on zirconium tetrachloride. Ten years later de Boer devised a process—now known variously as the de Boer, the van Arkel, or the iodide process—based upon the thermal decomposition of zirconium iodide by a glowing coil of wire. This process for the manufacture of ductile zirconium has been used commercially. The other principal process of making zirconium on a large scale is that due to Kroll, whose name is now so well known in connexion with the production of titanium metal. The Kroll process involves reduction of vaporised zirconium tetrachloride with molten magnesium, in an atmosphere of argon. This process had been studied previously by von Zeppelin, but he had not been able to make it yield a satisfactorily ductile metal.

DIFFICULTIES OF LARGE-SCALE PRODUCTION

While both the original van Arkel and the Kroll processes yield a good ductile metal, and are satisfactory for producing the metal in relatively small quantities for special purposes, where expense is not of primary importance, they do not seem, in their present forms, to lend themselves to large-scale production at a price low enough to encourage wide use of the metal in the variety of applications for which its unusual combination of properties makes it potentially suitable. Accordingly, a number of variations in the original processes have been devised; for example, the zirconium tetrachloride may be both purified and reduced in a single operation.

While production of zirconium in the United States is based primarily on some form or another of the van Arkel or the Kroll process, a variety of other different possibilities are being closely examined, and it may well be that one of these will ultimately be adopted for production of the metal in bulk if substantial uses for it seem to be assured. One of these entails the reduction of zirconium tetrachloride with hydrogen in an electric furnace, but in its present form this apparently uses too much electric power to be commercially attractive. Another possibility is the reduction of zirconium oxide with calcium or magnesium metal; this is commercially attractive, but presents considerable technical difficulties.

As has been mentioned, Davy unsuccessfully sought to obtain zirconium by electrolysis more than a century ago, but this possibility has lately been thoroughly re-investigated. The reactivity of zirconium seems to rule out all possibility of obtaining it by electrolysis of aqueous solutions of salts of the metal, but the electrolysis of molten salts (for example, a mixture of potassium zirconium fluoride and sodium chloride) will

certainly produce it. At present, however, the product is unsatisfactory, mainly because it is difficult to eliminate impurities and because the metal is obtained as a powder rather than as the dense sponge, relatively easily worked up into malleable metal, which is the end-product of the Kroll process. The difficulty of converting the powder into ductile metal may be overcome; alternatively, zirconium may be found to lend itself to the techniques of powder metallurgy.

As ordinarily prepared, zirconium contains some 2% of the metal hafnium. For many purposes this does not matter, but for certain applications in the atomic engineering field—the needs of which have been the main incentive to the development of zirconium—the presence of hafnium cannot be tolerated. In this connexion the main interest of zirconium is that it combines a low absorption cross section for thermal neutrons (0·4 barn) with high melting-point and high resistance to corrosion. The absorption cross section for hafnium, however, is 101 barns, so that even traces of it can have a marked effect on the nuclear properties of zirconium. The great chemical similarity of the two metals—there is scarcely any other pair so closely alike—makes their separation very difficult. Throughout all ordinary chemical manipulations the hafnium remains firmly attached to the zirconium. While it is possible to effect the separation by traditional methods (but this would generally require laborious repetition of the same process several times over), ion-exchange chromatography seems to offer one of the best prospects for an industrial separation process. Distillation of the volatile alkoxides is another possibility. It is possible that outside the atomic energy field the hafnium that thus becomes available as a by-product may prove an acceptable substitute for zirconium, especially as it has an even higher melting-point.

The future development of the production of metallic zirconium is still uncertain. The stage has certainly been reached when there is no particular difficulty in making the metal in considerable quantities—of the order of some hundreds of tons a year—for special purposes. But the problem of making large quantities of the metal cheaply enough to encourage its wide use is still unsolved. It may well be that none of the processes which now excite the most interest will be that ultimately adopted for large-scale production.

While it is early days to say whether zirconium will ever find really extensive use—comparable with aluminium for example—it seems certain that its future in the atomic energy industry and for certain other special purposes is assured.

Among the special uses of zirconium may be mentioned its application as a "getter"—substances used to remove the last traces of gas—in radio valves. The fact that it will not amalgamate with mercury means that it can be used in mercury discharge lamps. It is also used in the radio industry to inhibit grid emission.

Zirconium also finds some use in surgery as an alternative to tantalum (which is slightly more toxic) in making skull plates and other devices for repairing or replacing bone.

ZIRCONIUM ALLOYS

Alloys of zirconium find a number of uses. Steels containing traces of the metal have been considerably developed in the United States and Canada, but less so here, and have been used for armour-plating; the metal is present in some magnetic alloys; zirconium-iron alloys are sometimes used to improve the grain of steel. Because of its avidity for sulphur, oxygen, nitrogen, and some other impurities, zirconium, in the form of alloy, is used as a "scavenger" for steel. Alloys with magnesium are noteworthy for their great strength and resistance to "creep". Addition of aluminium, tin, and titanium to zirconium still further increases the resistance to creep at high temperatures. A number of zirconium alloys used for special purposes such as these have been in limited production for a number of years.

Although zirconium metal is a comparative newcomer, and its future is still undetermined, zirconium minerals have long had an established place in industry and world production is now probably of the order of 35,000 tons annually. Rather surprisingly, indeed, zirconium occurs in nature less rarely than the far better-known metals copper and lead. Among the principal sources of ore are the United States, India, Ceylon, Australia, Brazil, and Malaya. As the ores are often found associated with ores of titanium, the very rapidly rising demand for the latter tends to make zircon production a more interesting economic proposition.

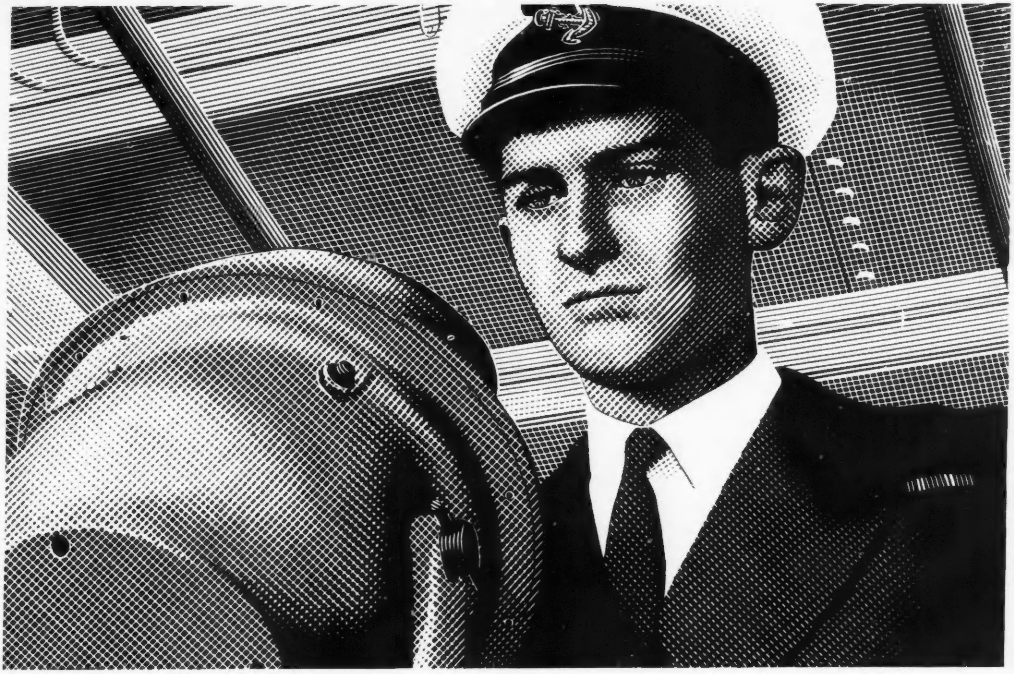
The main use of zirconium ores in industry is for the making of refractories. Zircon, the silicate, serves as an acidic refractory, while zirconia, Klaproth's *Zirkonerde*, has basic properties. These refractories have the advantage, when used as furnace linings, of not easily splintering when strongly heated. Foundries use considerable quantities of zirconium minerals; in casting it is useful for lining moulds which have to withstand high temperatures. It is useful also for lining furnaces in which aluminium is melted, since it is not wetted by the liquid metal.

Both zircon and zirconia find uses in the ceramics industry for the preparation of vitreous enamels, tending to replace tin oxide. Zircon cements are used as electrical insulators in places, such as heaters and furnaces, where the heat is intense. Zirconium-containing glasses, containing as much as 12% zircon, are used for special purposes, as the presence of the element increases resistance to corrosion and reduces sensitivity to heat-shock.

Zirconium compounds have many other uses which, although interesting and important in their own field, require only very modest quantities. These uses include the making of dental cements, water-colour pigments, glass-polishing powders, textile improvers, leather-dressing chemicals, and lighthouse lamps.

FURTHER READING

Readers who are interested in further details about the metallurgy of zirconium should consult the 374-page monograph by Dr. G. L. Miller of Murex Ltd. entitled *Zirconium* and published by Butterworths Scientific Publications in 1954.

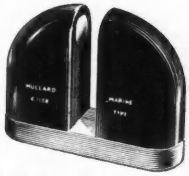


PROGRESS IN ELECTRONICS

Despite its innumerable applications, the magnet is still popularly associated with its use as a navigational aid. This is perhaps not surprising when one considers that the earliest experiments in magnetism were connected with the compass and its use in navigation.

It is said that the Chinese were using a form of lodestone compass in B.C. 2637, but the experimental study of magnetic direction finding devices really began in A.D. 1000 and reached something of a milestone in the 16th century with the work of Dr. Gilbert, who was physician to Queen Elizabeth.

It is only within the last twenty years, however, that revolutionary advances have been made in navigational aids. Radar was, of course, the most important of these advances and it owed its successful development to the invention of an electronic tube known as a magnetron, and this device, in turn, depended for its efficiency upon the "Ticonal" permanent magnet —an alloy having great field strength, stability and uniformity.



Mullard's work in the field of magnetic materials has been particularly outstanding. In addition to "Ticonal" permanent magnets, two other materials now in quantity production are Magnadur, a non-metallic permanent magnet, and Ferroxcube, a non-metallic H.F. core material. These materials are contributing to important developments in other electronic applications such as television receivers and line communications equipment.

Progress in magnetic materials continues, and through this the future may well see developments of equal significance to those which have gone before.

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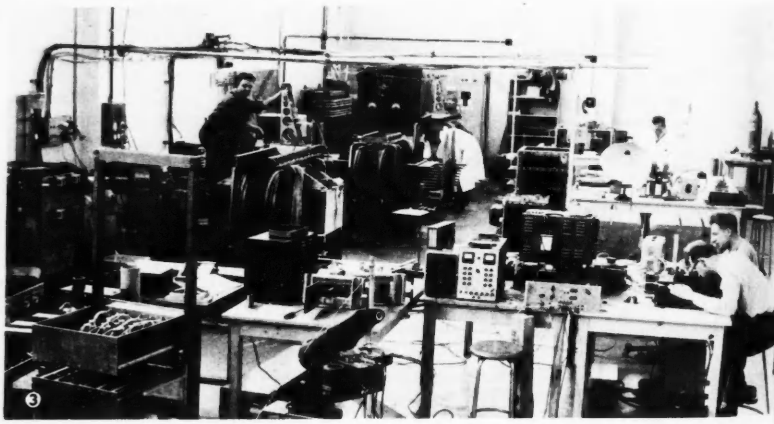
EUROPE'S NEW [C]ENT
FOR NUCLEAR [R]ESEA

On June 10 the foundation stone of the headq[ua]rters and lab the European Organization for Nuclear Rese[arc]h was laid, incident in a sequence of events that started in [19]50. When its have been built and equipped, and its powerfu[l p]article accele been erected, there will be no finer centre for fu[nd]amental nucl in Europe. The idea for this centre grew out of [th]e proposal of General Assembly that groups of nations shoul[d] collaborate t set up regional research laboratories. To prepare [pl]ans for the i nuclear research centre an interim body, CERN [(C]onseil europ Recherche nucléaire) was established. From this [bo]dy has been permanent Organisation Européenne pour la Re[che]rche Nucléair the following governments are now members: [Bel]gium, Denma German Federal Republic, Greece, Italy, Neth[erl]ands, Norwa Switzerland, Yugoslavia, Britain. These nations [are] sharing the structing the new laboratory, which is estimated [to cos]t more than This year's budget is about £2 million. Britain [is] a major supp tributing 23·84% of CERN's income) and an [En]glishman, Sir speiser (secretary of the DSIR) is CERN's p[res]ent president outstanding pieces of equipment which are to [be] erected are proton synchrotron and the 600 MeV synchr[o-c]yclotron, ba designs and experimental work of two teams o[f] scientists wo CERN'S Director-General.



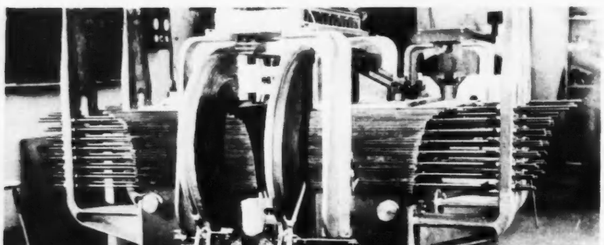


FIG. 1. Early construction work on the Meyrin site (close t[o] Geneva's airpo organization for Nuclear Research, with the Jura mount[ain]s in the backgr

FIG. 2. Prof. C. J. Bakker, who takes over as Director-Ge[ne]ral of CERN For a period he has been the Deputy Director-General. U[n]der him come fi Prof. W. Gentner, J. B. Adams, C. Møller, L. Kowarski and L. Preiswerk

FIG. 3. The proton synchrotron project has involved a va[st] amount of scien has been working in the Institute of Physics in Geneva, is [no]w headed by J.

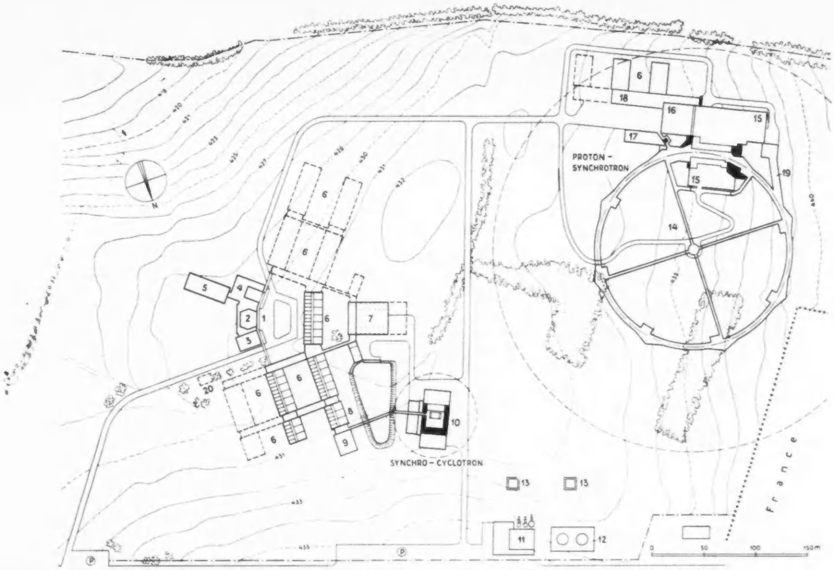
FIG. 4. The design of the giant magnet for the proton sync[hro]tron presented involved a series of pilot-plant studies with smaller mag[net]s such as this.

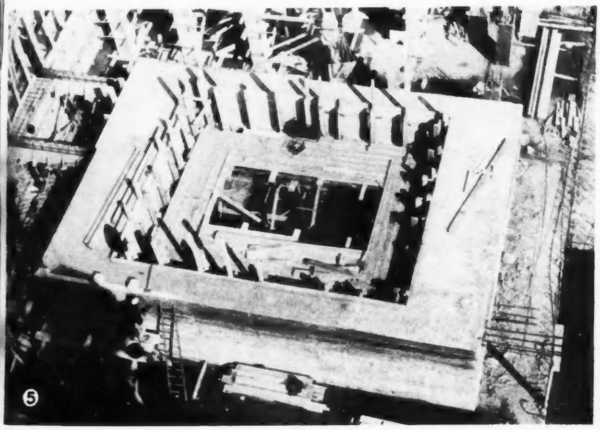
FIG. 5. Compared with the proton synchrotron, the sy[nc]hro-cyclotron proposition. Its construction, it has been estimated, shoul[d b]e completed d the site began in July 1954, and the work of laying the [co]ncrete foundati was well under way when this photograph was taken.

FIG. 6. The model of the proton synchrotron building: [co]mpare with gro based on a diagram originally published by *Schweizerisch[e] Bauzeitung*.)

NEW ENTRE
AR ESEARCH

e of the headqrters and laboratories of Nuclear Reseh was laid, an historic hat started in 0. When its laboratories nd its powerfu article accelerators have er centre for fu mental nuclear research re grew out of proposal of the Unesco nations shoul collaborate together and es. To prepare ns for the international body, CERN Conseil européen pour la ed. From this dy has been formed the ne pour la Re rche Nucléaire, of which w members: ium, Denmark, France, ce, Italy, Neth nds, Norway, Sweden, These nations sharing the cost of con- ch is estimated more than £10 million. illion. Britain a major supporter (con- me) and an ishman, Sir Ben Lock- is CERN's p nt president. The two which are to erected are the 25 BeV MeV synchr yclotron, based on the f two teams scientists working under





⑤

Key to ground plan of European Institute for Nuclear Research:

1. Entrance.
2. Lecture theatre.
3. Library.
4. Restaurant.
5. Theoretical laboratories and administration.
6. Experimental laboratories.
7. Central workshop.
8. Workshop for synchro-cyclotron.
9. Control station for synchro-cyclotron.
10. Synchro-cyclotron.
11. Power plant.
12. Oil tanks.
13. Cooling towers.
14. Ring building for proton synchrotron magnet.
15. Experimental halls.
16. Workshop for proton synchrotron.
17. Generator room.
18. Theoretical laboratories.
19. Linear accelerator.

rin site (close Geneva's airport) of the laboratories of the European e Jura mounta in the background.

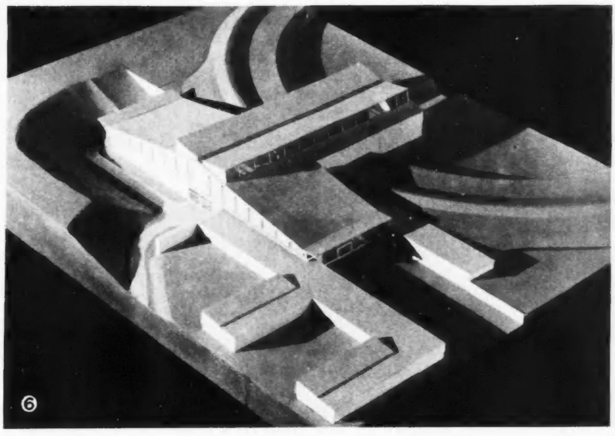
as Director-G ral of CERN this September from Prof. Felix Bloch. tor-General. der him come five scientific divisional directors, namely , L. Kowarski nd L. Preiswerk.

s involved a va amount of scientific work. The team responsible, which s in Geneva, is w headed by J. B. Adams.

he proton synch tron presented many problems, and their solution has smaller magn such as this.

rotron, the sy ro-cyclotron project is a relatively straightforward timated, shoul e completed during 1957. Excavation on this part of of laying the ncrete foundations on which the instrument will rest was taken.

tron building: mpare with ground plan above. (The ground plan is *Schweizerisch Bauzeitung*.)



⑥

THE REVOLUTION IN WEEDKILLING

F. D. SMITH, D.Sc.

Science has revolutionised the business of weedkilling in the past decade. This article describes the extent of the revolution, and refers to the farmer's readiness to exploit to the full the potentialities of the discoveries made by scientists in this field. The author is an ex-Admiralty scientist with an 80-acre farm. He mentions some of his own experiments with newer techniques of scientific weed control.

When first I took to farming, many years ago, I was primed with plenty of book knowledge, but I lacked practical experience. I thought that if I attended to cultivations and such conventional arts of good husbandry, good crops would surely follow. I assumed that these crops, in proper rotation, would sufficiently smother and choke out the weeds. I now know differently.

Weeds are not so easily mastered. They present a much more positive problem. It is not too much to say that husbandry must be planned with the specific object of *not* growing particular weeds. Let me give an example. I have a field of heavy clay—typical "wheat and bean" land—which, planted to winter wheat, yields abundantly. But autumn cultivations and planting give no control of the crow onion (*Allium vineale*). Its stinking seeds, harvested with the corn, make it unsaleable except at a low price. I have to forego the advantages of autumn planting in order to be able to work the land in the spring, which is the only season when crow onions are vulnerable.

It is the same with the permanent pasture. I must order my husbandry, not only to grow good grass and clover, but also to check buttercups and thistles which thrive on this soil. Indeed, every field presents its own special weed-problem—charlock here, cleavers and chickweed there, and thistles everywhere!

The open fields are only a part of the weed-problem. Weeds flourish in every waste corner of the farm. They infest the hedgerows. They disgrace the yards and buildings. Regular cutting with hook and scythe is the traditional remedy. Given sturdy farmworkers in sufficient numbers, toiling for long hours for little pay, such regular cutting yields superb results. There was a time when even the hedgerows were cultivated and cleaned like a garden. Mechanisation has, however, made such work intolerable and happily farmworkers are no longer asked to toil long hours for little pay.

A well-paid farmworker, accustomed to control 50 horse-power at his finger-tips, does not take kindly to frustrating toil with only his own fractional horse-power at command. And thus it comes about that those parts of the farm out of reach of the plough and the mowing machine, have become a modern problem. The mechanised hedge and brush cutters offer a solution, but such equipment is costly and usually beyond the reach of the average farmer.

Faced with such problems of weed-control, not only in the fields, but also in the hedgerows, and in waste places, I have naturally taken the keenest interest in the spectacular progress which scientists have made and are still making in the control of weeds by chemicals.

I well recall the first time we asked a contractor to spray charlock in corn with sulphuric acid. He provided the machine and the acid. We hauled the water. We worked carefully, but in subsequent weeks we not only watched the charlock die, we also watched holes appear in our clothes!

Later, we came to regard such damage to clothes as a minor peril. The much greater dangers inherent in the use of DNC, a later alternative to sulphuric acid, were not then fully realised. (Table I gives the chemical name of this compound and other herbicides.) Deaths occurred among employees of spraying contractors. These fatalities focused urgent attention upon the risks inherent in the use of DNC and some other chemicals used on the farm. Unfortunately the first symptom of such poisoning by DNC is a change in the body's metabolism, which produces an illusory feeling of well-being. Thus contractors who asked their workers if they were feeling all right, received deceptive answers.

TABLE I. LIST OF WEEDKILLERS AND THEIR ABBREVIATIONS

DNC	dinitro-ortho-cresol
MCPA	2-methyl-4-chloro-phenoxyacetic acid
MCPB	2-methyl-4-chloro-phenoxybutyric acid
2,4-D=DCPA	2,4-dichloro-phenoxyacetic acid
2,4,5-T	2,4,5-trichloro-phenoxyacetic acid
dinoseb	dinitro-secondary-butyl-phenol
TCA	trichloro-acetic acid

The risks to workers spraying certain poisonous chemicals are now fully appreciated and the Agriculture (Poisonous Substances) Act, 1952 prescribes the use of protective clothing and other measures to safeguard the men. In practice, farmers now do a great deal of spraying with the non-poisonous sprays but most of them leave the poisonous spraying to contractors, who install special equipment, such as pressurised cabins with filtered air supply on their tractors.

My first trial of the then novel hormone weedkillers was some years ago, when a dense crop of charlock appeared in a crop of corn sufficient to make it a total loss. A contractor sprayed the field with MCPA with quite spectacular results. In the following season, I planted again and this time, a stand of different weeds appeared, which again called for treatment. Among these were cleavers and chickweed, both of them resistant to the hormone type of weedkiller. The problem was solved by contract spraying at high volume* with

* High-volume spraying delivers a large volume of liquid spray, say 70–120 gallons per acre, in contrast to low-volume spraying for which the quantity varies between about 5 and 20 gallons per acre.

DNC. Again, a good crop resulted. This same field was later successfully undersown to grass and clover.

Striking successes of this kind are now, of course, the common experience of tens of thousands of British farmers. The huge booms and heavy equipment of the spraying contractors have been supplemented by a very large number of small tractor-mounted tanks and spray booms, driven from the tractor power take-off. In 1942, there were about 2000 sprayers. At the end of 1952, there were 9330 sprayers. Merely two years later, at the end of 1954, there were 18,260 sprayers.

The "know-how" of hormone weedkilling, at first the monopoly of experts and contractors, is now the standard practice of the ordinary farmer—even of the family farmer. This refutes the accusation, so often brought against farmers, that they are slow to take advantage of scientific progress. They are quick enough to adopt any discovery that really solves their problem. Bearing in mind that farmers had to find the money—a tractor-mounted sprayer cost from £50 to £100—to double the number of sprayers in about two years, is indeed rapid progress.

It was of course to be expected that the amazing initial success of the hormone weedkillers, such as the now well-known MCPA and 2,4-D, in killing such troublesome weeds as charlock, would stimulate an intensive search for new herbicides. I learn that at least a dozen new substances have shown promise, mostly in trials made in the U.S.A. These await for the most part full trials in this country, not only to assess their value in weed-control, but also to ascertain if they are poisonous to man or beast.

Typical of these is trichloroacetic acid, which offers to control, with suitable cultivations, that age-old scourge of farmers—couch grass (*Agropyron repens*). At present, the quantity of acid required to give good control costs rather much, but no doubt the chemical will be cheaper when the use of it justifies large-scale production.

Among later discoveries, dinoseb (DNSBP) is specially important, because many leguminous crops of the farm are relatively resistant to it. These include lucerne. Lucerne is valued for its deep roots which explore the subsoil for plant nutrients, but lucerne is notoriously difficult to establish in its early stages, since it competes rather weakly with weeds. Also included among these leguminous crops are winter beans, a difficult crop to clean by mechanical means upon the very heavy clays on which they flourish; peas, which at quite an early stage of growth fall across the rows and hinder inter-row cultivations against weeds; and sainfoin, so valuable on the thin Cotswold soils, which is also sufficiently resistant to allow the use of dinoseb. Even the clovers, upon which the farmer relies to fix nitrogen from the atmosphere in quantities altogether beyond his resources to supply out of the bag, can with care be cleaned of weeds by a dinoseb spray. Practical use of this chemical on the farm is still in an exploratory phase. So many variables influence the results. For example, on a warm day following a period of active growth, it is prudent to reduce the dose. The results obtained are, however, sufficiently encouraging to leave no doubt that farmers and contractors will speedily master the "know-how".

A more recent herbicide, MCPB, has the supreme virtue of killing a variety of weeds without affecting grasses and *clovers*. Farmers will not hesitate to exploit to the full this compound which will hasten the hitherto slow process of establishing a clean, weed-free ley.

Among the modern uses for new herbicides, I have been specially interested, from my own farming point of view, in the control of woody weeds by hormone weedkillers. The well-known 2,4-D and the more recent 2,4,5-T are both effective in controlling a wide range of the shrubby plants that constitute brush or scrub. In particular, the troublesome brambles happen to be susceptible. This is important for several reasons. In the first place, the usual method of dealing with brambles by cutting and burning, leaves the root-system unimpaired and the bushes spring up again quickly, almost, it seems, with renewed vigour. Brambles also spread by their habit, particularly odious from the farming point of view, of rooting readily wherever their long canes bend down and touch the soil. By this means they span and obstruct ditches, encroach upon the pastures, and infest the hedgerow, where they compete vigorously with valuable hedgerow plants, such as the whitethorn.

Fortunately, hawthorn (*Crataegus monogyna*) is resistant to 2,4-D and moderately resistant to 2,4,5-D, and the way seems open to treatment of hedgerows in order to suppress woody weeds, especially brambles and briars. For this purpose, the spray is applied by a hand-lance or spray-gun, rather than by a multi-nozzle boom, so that the worker can apply the spray more or less where it is wanted.

Such treatment of brambles and other woody weeds does not always effect a complete kill. Some parts of their complex ramifying root-system may not be reached by the translocated herbicide before the death of the main part of the plant arrests its further penetration. Thus, some feeble growth of suckers is not unlikely in following seasons. Nevertheless, the ability of the brambles to compete with the thorns is gravely impaired, and generally sufficient to enable the latter to dominate the hedgerow.

Our knowledge of the susceptibility of various woody plants and weeds to hormone weedkillers, such as 2,4-D and 2,4,5-T, is still incomplete. Broadly speaking, these chemicals act in a similar way, the resemblances being more marked than the differences. However, some woody weeds are rather more susceptible to the one than the other. Manufacturers formulate "brushwood" killers to include both.

It appears that the season in which spraying is done is a vital factor. Spraying in the late spring and early summer, when sap flows freely and growth is active, reveals very marked differences in the susceptibilities of various species. By contrast, spraying in winter when the plants are dormant, reveals little difference between species. Practically all are susceptible. By winter spraying, practically a complete kill of brush and scrub can be achieved.

FIG. 1. *The farmer's use of weedkillers on pasture parallels the gardener's use of 2,4-D on lawns. This picture shows the elimination of buttercup by an MCPA preparation sprayed at five pints an acre: the centre strip was untreated.* (Plant Protection photo.)
FIG. 2. *Typical sprayer for applying weedkillers to farm crops, in this case DNC at high volume to hormone-resistant cleavers and chickweed in corn.*
FIG. 3. *Control of weeds in lucerne by DNBP; the right-hand strip was treated.* (Courtesy, Mr. G. O. P. Eaton).

As regards summer spraying, we know that the following are *susceptible*: alder, silver birch, hazel, bramble, elder, broom, rowan, gorse and willow. We know too that the following are *resistant*: hawthorn, ivy, holly, juniper, oak, rhododendron. The classification is tentative only. There are degrees of susceptibility and of resistance. Much depends on conditions of weather and so on, which prevail at the time the spraying is done.

Winter spraying requires a different technique from summer spraying. The hormone weedkillers are applied in winter as an *oil* spray, whereas they are applied in summer as a *water* spray. Almost any oil commonly used on the farm can be used, provided that the viscosity is suited to easy spraying. Tractor vaporising oil is excellent for the purpose and discarded sump oil can be mixed with it. Gas oil is quite effective, but workers object to using it because of its extremely unpleasant and persistent smell, for it is almost impossible to prevent clothes from receiving some spray!

I find that my farm offers considerable scope for the use of such brush killers—for instance, it destroys rubbish growing up through wire fences: brambles obstructing ditches and watercourses: unsightly stands of nettles about yards and buildings: thickets of brush in waste corners of fields. There is still need for cutting, cleaning and burning of such rubbish, but the brush killer has the great advantage that it penetrates to the *roots* of the scrub.

It can hardly be expected that the various uses of hormone weedkillers would be everywhere received with acclamation. Indeed, scientists have almost come to expect the gloomiest forebodings of evil consequences likely to follow the applications of their latest discoveries. In the matter of hormone weedkillers, the Highway Authorities have become the scapegoats. Looking over the roadside hedge, they have followed the example of farmers in spraying their arable and grassland and have sprayed their own "Long Farm"—those miles of grassy verge along the highways. Massive stands of verge weeds, such as the rampant cow parsley (*Anthriscus sylvestris*) and various species of docks, nettles and thistles, have become an obvious target for hormone weedkillers.

The Highway Authorities have been forced to adopt this new method by the problem of getting the verges cut. The old-time roadman, with his hook and his scythe, has drifted away from the lonely highway and his cheerless sandwich lunch in the open in all weathers and has sought work in the factory with its five-day week, congenial company, "Music While You Work", and cheap canteen hot dinner. In my county, the Highway Authority has to transport roadmen daily in lorries long distances from one area to another in order to get any cutting done at all. The cutting has of course been expedited by the use of tractor-mounted mowing machines, but even so the task of cutting hundreds of miles of verge in the short season of most rapid growth is very difficult.

The sight of the verge weeds dying from the hormone spray in full view of the travelling public, added to the

smell, aroused a storm of protest. It was said that rare plants would be irretrievably lost: that beneficial insects would be destroyed, and also valuable spiders: that the balance of Nature would be upset. It was feared that the pretty leafy lanes, the haunt of primrose and violet, and the joy and pride of the English countryside, would be reduced to unsightly stinking decay.

It must be admitted that potent mixtures of 2,4-D, reinforced with the even more powerful 2,4,5-T and formulated with oily substances, have not only punished the weeds, but have also scorched the grasses. The Highway Authorities have in the main confined such trials to the main roads loaded with heavy industrial traffic, along which none walk for pleasure and no flowers grow. But inevitably the spraying of roadside verges had to be done in full view and the public literally had their "noses rubbed in it".

Within the limitations of the present tentative trials, some promising applications along the highways have been reported. Scrub on roadside verges has been killed and the laying of mains and cables in the verge thereby facilitated. Vigorous crops of weeds following any disturbance of the verge soil have been suppressed and a more pleasing herbage quickly established. Many of the neglected footpaths and bridle roads that have recently become the responsibility of the Highway Authorities are being cleared of obstructing brush and scrub by chemical means. The economies that follow on such methods are well worth while. The annual bill for verge cutting in one single county—Gloucestershire—amounts to no less than £26,000, which leaves plenty of scope for saving.

More informed criticism of hormone weedkillers has come from some experts and some farmers. They consider that the early promise has not always been fulfilled. They point out, quite rightly, that there is little point in killing one susceptible weed when an even more troublesome resistant weed may appear to take its place! It is perfectly true that some hormone-resistant weeds have been much more in evidence in recent years. A notable example is the wild oat, which has become a major problem, especially in East Anglia. On my own farm the wild oat is increasing, and I also notice that cleavers and chickweed are becoming troublesome.

I hold the view, however, that much of this criticism is misconceived. Chemicals are by no means a universal panacea for weeds. They are by no means a substitute for good husbandry. On the contrary, they are rather an expedient which a farmer has in reserve, when weeds for one reason or another temporarily gain the upper hand.

There may be farmers who, seeing a crop of weeds, destroy them with hormone weedkiller and give the matter little further thought. But some weeds may be an indication that something is amiss with the husbandry. If a field suffers from lack of lime, certain weeds and inferior grasses characteristic of lime-deficiency flourish. To apply hormone weedkillers to such weeds cannot lead to a better herbage; such action can only result in a change in the composition of the herbage in favour of those weeds and inferior

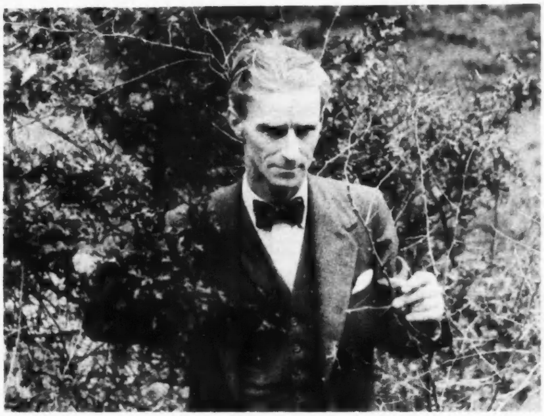


FIG. 4. Brush killing by selective weedkillers. The typical thicket seen here was sprayed in early summer; the hawthorn in the experimenter's right hand has survived, but the briar he is holding in the other has succumbed.

grasses that are the more resistant to the weedkiller.

The question of costs in relation to the results achieved is, of course, as vital to farmers as to the Highway Authorities. In the case of a very susceptible weed, such as charlock, infesting a crop of corn, as little as a quarter of a pint per acre of a selective weedkiller, based on 2,4-D, gives control at a cost for the chemical only of about five shillings per acre. Similarly, general weed control in cereals, requiring half a gallon per acre, costs only ten shillings per acre for the chemical. Moreover, spraying by the usual small tractor-mounted sprayer covering a 20-foot width at 4 miles an hour is both speedy and cheap.

The economic argument for the use of weedkillers, based on DNC, for the control of weeds resistant to the hormone weedkillers—such as cleavers and chickweed—is not so spectacular but quite convincing. This substance being rather poisonous, farmers usually entrust the work to contractors at about £3 per acre.

Such spraying of weeds in cereals relieves them of weed competition and thus leads to higher yields, of the order of two to three hundredweights per acre, worth, say, £5. Moreover, harvesting the clean crop is easier, the corn requires less drying and cleaning, and the soil is cleaner for subsequent cropping.

Corn-farmers have found the economic argument for acquiring their own sprayers quite irresistible, and even family farmers with only 30 acres to spray think the outlay worth while.

The economic case for some of the newer weedkillers is rather more in doubt. It has been shown, for example, that the alternative methods of killing weeds in peas—by hoeing or by spraying with dinoseb—both result in an extra yield of three hundredweights per acre. But whereas hoeing by farm labour costs 7*s.* 6*d.* an acre, dinoseb spraying by contract costs £4. There are, however, times when the best farmers, impeded by adverse weather, lose control of weeds and turn gratefully to

the use of this spray to extricate them from their difficulties.

Again, TCA (in the form of sodium trichloroacetate), outstanding for the control of couch grass, costs from £10 to £12 an acre at the dose thought by some authorities to be necessary. Thorough cultivations cost less than this.

The general use of TCA and other new but costly chemicals must obviously depend upon a reduction in the manufacturing cost. Experience has shown that where the potential use exists, such reductions presently follow. For example, the price of a gallon of brushwood killer, formulated with 2,4-D and 2,4,5-T, has already fallen by about 10%, and doubtless further reductions will follow as the increasing use of it justifies manufacture on a larger scale.

Such then is the progress achieved on farm and highway in a mere decade! For it was not until 1945 that weedkillers based on MCPA were introduced on a commercial scale. Much remains to be done. Farmers set the scientists a hard task. They ask for *cheap* weedkillers to control *any* weed in *any* farm crop. The scientists do not regard such a demand as beyond reason. On the contrary, they accept it as a possible, though very difficult, target.

READING LIST

There are four chapters on weedkillers in the new book by Dr. E. Holmes entitled *Practical Plant Protection* (published by Constable, 15*s*.). Another new publication worth consulting is a 2-volume work entitled *British Weed Control Conference 1954: Proceedings* (published by the Association of British Insecticide Manufacturers, 30*s*.). An article by Dr. E. K. Woodford in *The Chemist and Druggist* (1955, vol. 163, pp. 171–4) gives a useful list of proprietary names for various hormone weedkillers and the plants that these control.

THE CAMEL RIDDLE ANSWERED

The camel's ability to go without water has interested most of us at some time. It used to be said, and still is in some encyclopaedias, that the camel stored water in its hump, but this is quite untrue—the hump is made of fat. Some people have said that it stores water in one of its several stomachs—for the camel, like the cow, has several stomachs and goes through the routine of rumination or chewing the cud. This belief, too, has now been disproved.

The whole mystery has now been cleared up, at any rate to the extent that we can describe the mechanism with which a camel retains its water. This is the result of an investigation of the physiology of the camel carried out under the auspices of the Unesco Advisory Committee on Arid Zone Research. The leader of the research team was Prof. Schmidt-Nielsen of Duke University, U.S.A. Behind it lies a year of intensive work at a place called Beni Abbes, 800 kilometres inside the Algerian part of the Sahara Desert, a place where the temperature often reaches 140°F.

To understand how the camel does this extraordinary trick, first let us consider ourselves. The whole complex business of metabolism cannot go on without water, and our lives are bound up in the routine of taking in water and getting rid of it. Normally we lose water from the kidneys and by normal sweating from the skin, and if we don't sweat enough the blood temperature goes up.

With camels it is quite different, and it is the cumulative effect of several specialisations in their body economy that enables them to go for a long time without water.

For instance, it excretes very little from the kidneys, something like 500 cubic centimetres a day even when it has all the water it can drink. Man excretes many times as much. Another way of conserving water is not to lose it by sweating. In this the camel is unique. Its body temperature can go from about 93°F to as much as 104°F, an increase of 12% without any sign of ill-health. Over its range it does not sweat. But 104°F is the danger temperature, so to speak, for as soon as the blood gets to this temperature, but not until then, the sweat glands begin to work. This tolerance of a rise in blood temperature five times as much as we could stand without going to bed sick lets the camel live through considerable rises in outside temperature without sweating. So in this way it conserves its bodily water.

But suppose it has to endure high temperatures above 104°F. Then, you will protest, it will sweat and lose water. But here one meets an extraordinary feature of the camel's physiology. True, it does lose water, but not from the blood. Somehow, as it loses water by sweating, the blood keeps its fluid content constant, and this is done by depriving the body tissues of their water. So for a considerable rise in temperature beyond the non-sweating limit, the camel's metabolism goes on undisturbed and its blood pressure is maintained. It does this at the expense of its tissues, and its overall metabolism therefore stays more or less normal.

A further protective device that helps the camel to conserve its water supply is the thick fur of its coat. This is an insulator and so helps to absorb heat from outside and prevent it from getting through to the body. Thus a rise of outside temperature that would, if immediately effective, drive the camel's temperature beyond the non-sweating limit, is tolerated because of the insulating layer of fur. Experiments with camels shorn like sheep have made this fact certain.

The result of all these unusual mechanisms added together is that the camel can survive for very long periods—indefinitely, in fact, in winter—without drinking.

C. L. BOLTZ

(This script is the substance of one of the regular talks broadcast by the Science Correspondent of the BBC's European Service.)

THE BUBBLE CHAMBER

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The list of ingenious devices for detecting the fundamental particles of nuclear physics is growing longer and longer. So indeed is the list of fundamental particles itself, and these two facts are not unconnected: it is often new detectors that detect new phenomena, and in turn the study of the new phenomena can necessitate the development of new techniques. Amongst the latest developments in particle-detection methods, one which is both striking and outstandingly promising, is the bubble chamber invented in 1952 by Dr. D. A. Glaser of Michigan University, and first described in *The Physical Review* (vol. 91, p. 762). Interest in this instrument is already widespread, and its development is going ahead rapidly in several countries.

The apparatus is simply named and can be equally simply described: the bubble chamber is a device in which the path of a charged particle through a liquid is made visible by the string of bubbles left in its wake. Dr. Glaser's apparatus is the latest addition to the group of particle detectors in which the tracks of particles through a more or less transparent medium can be photographed or even seen with the naked eye; thus it can be classed with the Wilson cloud chamber, the nuclear emulsion, and the newer types of cloud chamber such as the diffusion chamber.

One may wonder why, when nuclear physicists have already a great many detectors to choose from, they have shown such interest in the bubble chamber. The answer is that no one detector is without its drawbacks, and the bubble chamber has some differences from the others which enable it to avoid some of their drawbacks—particularly one or two that have been seriously felt since the advent of large accelerating machines such as cyclotrons. Let us enumerate some of the properties which an ideal particle detector of the cloud chamber type should have. It should *faithfully* reproduce the path of the particle in a form suitable for photography, i.e. the path should not be distorted by the operation of the instrument; it should record just the particles which the experimenter wants to examine, free from entanglement in or contamination by unwanted "background"; it should be as nearly instantaneous in its action as possible so that little time is wasted in resetting after each photograph—this is to make best use of accelerators which deliver their output of fast particles in rapidly repeated pulses; its transparent medium should contain just that sort of matter which the experimenter would like his incoming particles to interact with, and this matter should be of a suitable density; and if, in addition, the apparatus could be simple to construct and maintain, then it would be well on the way to being an ideal detector. How well the bubble chamber meets these demands will be indicated below, but first we must describe how it works.

SUPERHEATING AND BOILING

Dr. Glaser's preliminary experiment is instructive. Fig. 1 shows liquid ether contained in two connected Pyrex bulbs immersed in hot oil baths. The temperatures are higher than the normal boiling-point of ether at atmospheric pressure, i.e. 34·6°C, but the ether is not boiling because the system is sealed and the pressure within is increased. Now suppose the left-hand bulb is cooled. The vapour pressure in it rapidly falls, lowering the pressure in the whole system. At the now prevailing pressure the boiling-point of the ether on the right is much lower than the actual temperature and the liquid should accordingly boil violently. However, if the tubes are clean and smooth, the onset of boiling may be deferred for several minutes while the liquid—said now to be "superheated"—stays in a state of unstable equilibrium. This state has long been known to physical chemists, but Glaser showed that it would instantly end in an eruption of bubbles if a radioactive material was brought near the bulb; in other words, *a quiescent superheated liquid will begin to boil if charged particles pass through it.* This was the vital observation.

The graph of Fig. 2, based on experiments performed by Dr. C. Dodd of University College, London, illustrates the same phenomenon in pentane, a liquid

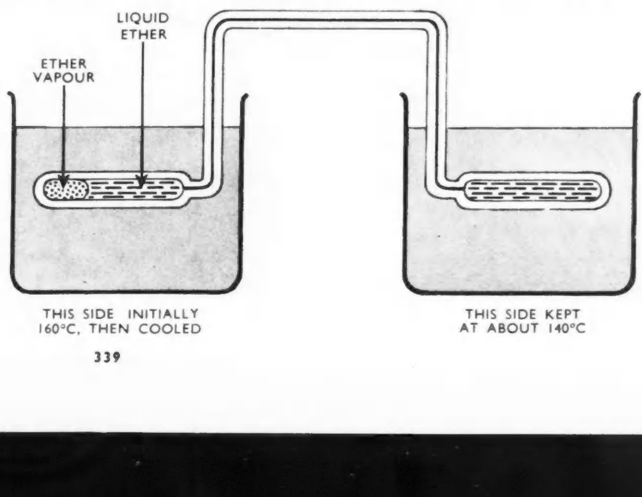
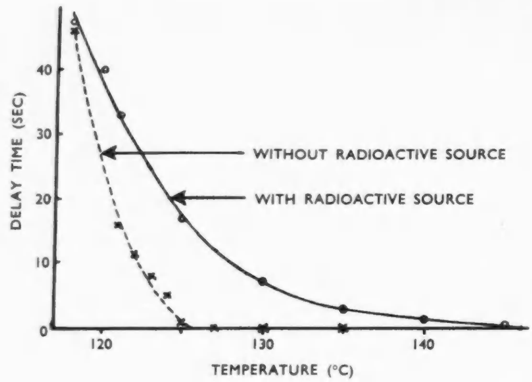
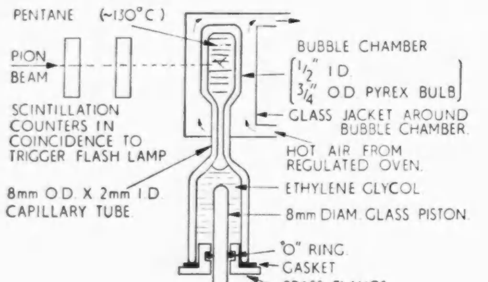
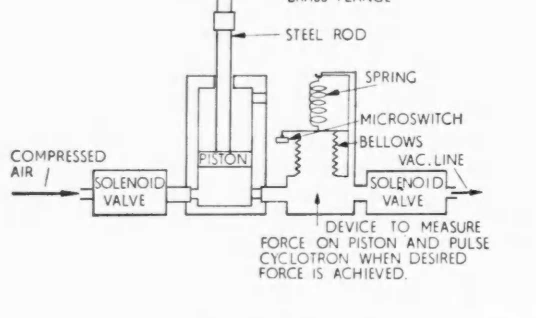


FIG. 1. Glaser's experiment on "triggered" boiling. The ether in the right-hand bulb is superheated but remains quiescent for an appreciable time. Boiling starts at once if a radioactive source is in the vicinity.







hydrocarbon. The full curve shows, for various temperatures, the time for which the liquid will remain superheated. The hotter the liquid, the shorter this time is, but even at 130°C boiling is delayed for about 8 secs. With a radioactive source present the boiling sets in much earlier, indeed at 125°C and upwards, and superheating cannot be maintained at all.

Workers with all types of cloud chamber will agree that it is one thing to make an apparatus which reacts in some visible way to the passage of a charged particle and another to refine it to such an extent that useful photographs of nuclear events can reliably be obtained. To understand some of the detailed development work consequent upon Glaser's experiment it is necessary to consider the boiling in more minute detail. The bubbles of a boiling liquid begin as very small bubble nuclei which grow rapidly as more and more liquid evaporates into them. Dissolved gases or irregularities of the container walls are prolific sources of bubble nuclei and encourage boiling as soon as the temperature is nigh enough. In their absence, the liquid may refuse to boil, becoming superheated as in Glaser's experiment. However, the wake of a charged particle in the liquid consists of a line of ionised atoms, and all along this line the local electrical charges resulting from the ionisation give rise to microscopic bubble nuclei which are themselves electrically charged. It has been demonstrated both theoretically and experimentally that these charged nuclei will grow large if the degree of superheating is above a certain level. The next important point is that the growth of large bubbles from small bubble nuclei is extremely quick; they may attain radii of the order of 1 millimetre in 0·1 millisecond. Therefore in order to photograph fine narrow tracks as opposed to clusters of big bubbles an apparatus must be developed in which there is (i) a clean liquid and container; (ii) a device for creating the superheated state; (iii) a means of photographing the bubbles very soon after the passage of the particle which started their growth; and (iv) a mechanism for recreating the superheated state after each outbreak of triggered boiling.

CONSTRUCTION AND OPERATION

An apparatus capable of giving good pictures was described by Dr. Hildeband of Chicago University in the proceedings of the 1954 Glasgow conference on Nuclear and Meson Physics. The construction and operation of bubble chambers can conveniently be described by reference to a diagram of his apparatus (Fig. 3) but it must be pointed out that chambers in other laboratories certainly differ in technical detail.

FIG. 2 (*top*). Delayed boiling in superheated pentane. The points represent average values from a large number of observations because, for a given temperature, delay time is not always exactly the same.

FIG. 3 (*centre*). Bubble chamber used by workers at Chicago University.

FIG. 4 (*bottom*). One of the ways of producing superheating. Instead of a movable piston there is a flexible diaphragm and pressure on the liquid in the bulb is reduced by removing the pressure on the outside of the diaphragm. (Compare Fig. 3.)

The chamber we are considering is a clean, smooth glass bulb of ½ in. inside diameter, filled with pentane. The pentane is kept at about 130°C initially under pressure, and then, to produce superheating, the pressure is sharply reduced by drawing down the glass piston by a suitable amount—about 1 millimetre. Under the reduced pressure and still at 130°C the pentane is ready to boil as soon as a charged particle enters to trigger it. The lower part of the apparatus is filled with ethylene glycol, a liquid which is far less likely than pentane to begin unwanted boiling in the neighbourhood of the rubber seal. The same mechanism which moves the piston switches on a pulse of particles from the cyclotron; they enter the bubble chamber through two counters connected "in coincidence". These two counters raise an important point of technique and their function is as follows: we have seen that photographs must be taken very soon after the passage of the particles. The flashlights must therefore be triggered just at the right time, and the two counters are arranged so that if, and only if, a particle passes through *both*—as all particles in the cyclotron beam must if they are to reach the bubble chamber—they send a triggering pulse to the flashlights within a few microseconds. Other, but less satisfactory, ways have been suggested for doing this. For instance, the triggered boiling produces sound waves, indeed it is quite audible. A gramophone pick-up pressed against the chamber wall has been used to receive the sound vibrations and to initiate the lamp triggering pulse. However, the reaction time of this mechanism is rather too long.

Assuming now that the picture has been taken, the next step is to recompress the liquid to remove the bubbles and prepare the pentane for the next expansion. The whole cycle takes less than a second

Bubble chambers in other laboratories are likely to differ from the one just described in shape, size, the nature of the filling liquid, and in the mechanical arrangements for producing the expansion. An alternative expansion mechanism favoured by some workers is shown in Fig. 4.

Examples of bubble chamber pictures are given in Figs. 5 and 6. The first was taken in the relatively small pentane-filled chamber at Chicago, operated by R. H. Hildebrand and his coworkers. It shows a π-meson track about 12 millimetres long. The second was one of a series in which a larger chamber built by Glaser was exposed to the high-energy proton beam given by the Brookhaven accelerator known as the Cosmotron.

GENERAL PROPERTIES AND ADVANTAGES

A main object of work with cloud chambers and bubble chambers is to record the interaction of particles with matter. If a charged particle traverses a given thickness of matter, the chance of seeing it do something interesting will be greater if the matter is denser, i.e. if there are more atoms per c.c. for it to interact with; or, to put this another way, if your detector has small volume the material had better be

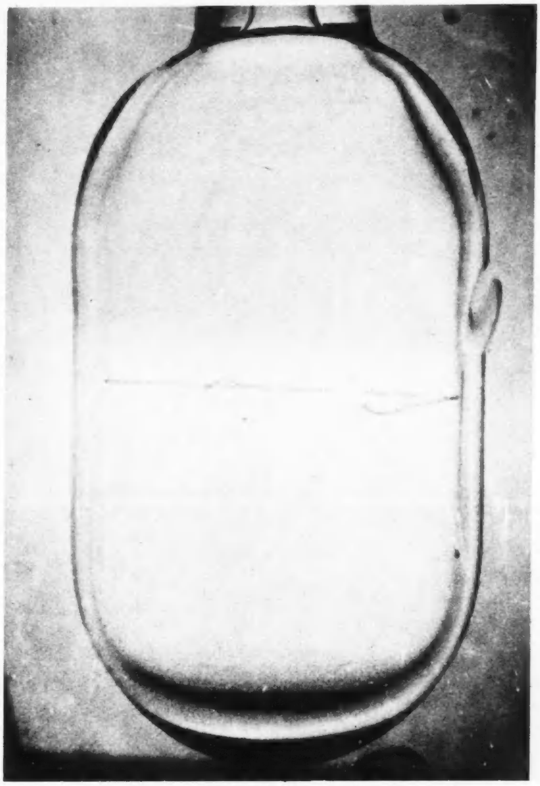
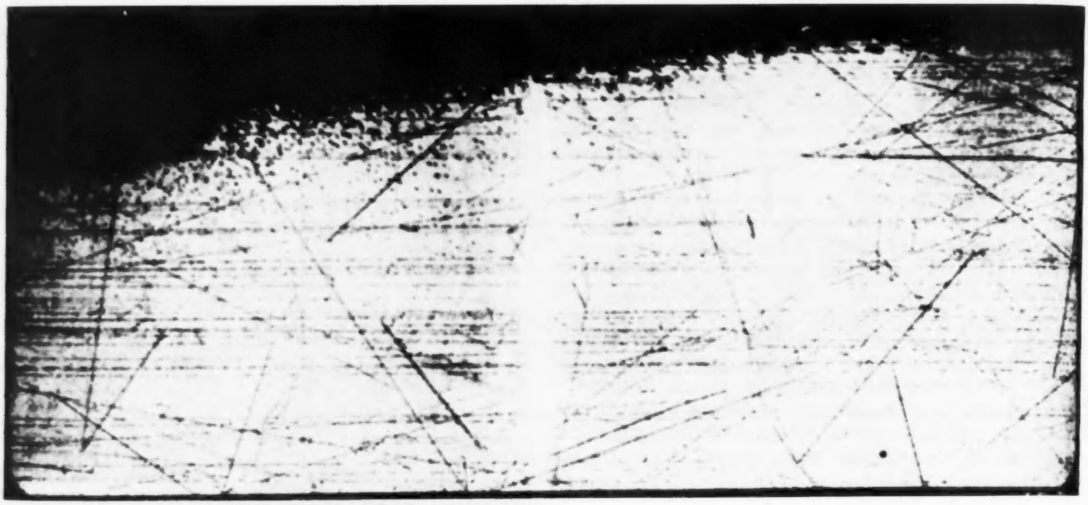


FIG. 5. Pentane-filled bubble chamber, measuring $1{\cdot}3 \times 1{\cdot}3 \times 2{\cdot}5$ centimetres. The track is left by a π-meson.

dense. Ordinary cloud chambers are gas-filled and gases are not dense unless, of course, they are highly compressed—a condition which for cloud chamber work brings difficulties of its own. Typical bubble chamber liquids have densities of about 0·5 gram per cubic centimetre (which is several hundred times the density of argon gas in an ordinary cloud chamber), and this is a great advantage. Furthermore, it is often desirable to allow the particles to react with a *pure* target substance, in particular with hydrogen whose nuclei, being protons, are of fundamental interest. Ordinary cloud chambers cannot be operated with pure gases; a condensing fluid such as alcohol must always be present. Bubble chambers can be operated with many pure liquids and, as the Chicago group showed, can even work with pure liquid hydrogen. This latter is a considerable technical feat since it adds to the normal difficulties of a new technique, the extra one of working at the very low temperatures necessary to liquefy hydrogen. The density of the liquids makes up for the small size of the early bubble chambers but small size is only a temporary limitation and chambers measured in feet instead of inches are already being constructed.

It is interesting to note that change in size involves



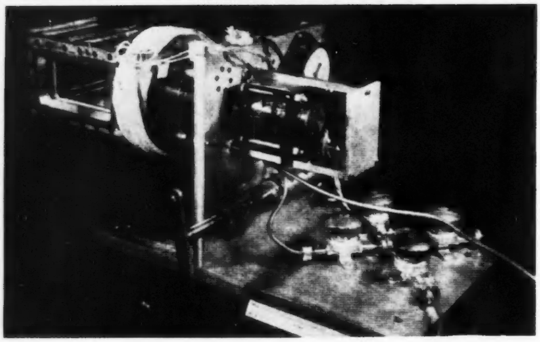


FIG. 6. Photograph of a beam of very energetic protons from the Brookhaven Cosmotron. The protons enter the six-inch-long pentane-filled bubble chamber on the left. Numerous oblique tracks result from interactions of the protons with nuclei. The black patch in the top left corner is due to violent boiling induced by the chamber wall. (*Photograph by courtesy of Dr. D. Glaser.*)

FIG. 7. The six-inch-long bubble chamber built by Dr. Glaser. The chamber with its glass window is on the left, and the expansion mechanism on the right. Fig. 6 was taken with this chamber.

a change in construction. Instead of being a blown glass bulb, a large bubble chamber is a metal box with sealed-on plate-glass windows. This is not a trivial change. The gaskets and sealing rings and the lack of smoothness at the corners of these chambers initiate boiling by giving rise to bubble nuclei and the liquid does not remain superheated for very long. Fortunately it is possible to photograph tracks in the main body of the chamber before the wall-induced boiling destroys the sensitivity (see Fig. 6).

Two or three important advantages are connected with the rapidity of the bubble chamber's cycle of operations. To have a short cycle, say of one second, is an advantage in itself because it avoids the uneconomic situation in which a large accelerating machine has to be kept idle while the detector resets itself for the next picture. Cloud chambers and even diffusion chambers are significantly slower in this respect. The actual time between the passage of the particles and the photograph may be only a few microseconds. This means that very few stray particles will have time to appear in the chamber and contribute to the background. Moreover, freedom from background is also ensured by the circumstance that stray particles that happen to traverse the chamber *before* it is superheated produce bubble nuclei which have a very short lifetime and do not survive to spoil the next picture. Distortion, too, is reduced to negligible proportions by the rapid operation. In ordinary cloud chambers distortion of the tracks is due to undesired convection currents in the chamber gas; this is something of a bogey in cloud chamber work and sets a limit to the accuracy of measurement. In the bubble chamber the tracks are photographed so soon after formation that convection has no time to take effect.

This new technique is still in its infancy and great refinements can confidently be expected. It still remains to develop reliable ways of identifying the different particles, perhaps by correlating the number of bubbles per centimetre of track with the ionising power of the particles. It even seems possible to make the chamber itself discriminate between particles by adjusting the degree of superheating so that the bubbles form for heavily ionising particles but not for lightly ionising ones. Bubble chambers will soon be operated in magnetic fields so that advantage can be taken of the fact that such fields curve the tracks into circles whose radii are proportional to the momenta of the particles.

The application of the bubble chamber to cosmic ray research is somewhat less promising because it seems very difficult to arrange for "counter control". Counter control is very important in cosmic ray work; it is a method by which cloud chambers are automatically operated some tens of milliseconds *after* counters arranged in their neighbourhood have indicated that some particle of interest has traversed the chamber. It means that pictures are only taken when there is a good chance of their being useful. Now bubble chambers take a definite, though short, time to expand and it seems that if one tries to expand *after* the particles have passed, the sensitivity will be created too late and the bubble nuclei will have disappeared. At present it is only possible to expand first and then send in the particle when the superheated state is reached. This is not such a disadvantage in nuclear physics since it is known when the next pulse of particles is coming and where from, but this is far from so in cosmic rays.

It would be pleasant to believe the story that Dr. Glaser conceived the idea of the bubble chamber while looking meditatively into a frothing glass of beer. This would put the invention into the time-honoured tradition of James Watt's steaming kettle. It is more interesting to note that in 1952 Glaser wrote: "For many problems connected with the study of high energy nuclear events . . . it would be very desirable to have available a cloud chamber-like detector whose sensitive volume is filled with a hydrogen-rich medium whose density is of the order 1 gm./c.c. In investigating possible ways of making such an instrument, it seemed promising to try to make a device which takes advantage of the instability of superheated liquids against boiling. . . ." The painstaking but quick work of several groups of physicists has already shown that Dr. Glaser's suggestion is fruitful. The bubble chamber works, and there is little doubt that before long it will be solving some nuclear problems and revealing others. Little more can be asked of any scientific instrument.

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POISONOUS PLANTS IN BRITAIN

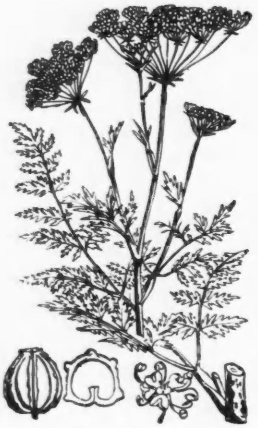
B. BARNES, D.Sc., Ph.D.

We may assume that man, long before he settled into organised societies, discovered by trial and error which plants were good for food, which had remedial properties, and which brought intoxication, illness and death; he must have paid heavily for the knowledge. Since he associated illness and death with the activities of evil spirits, it was inevitable that he connected injurious plants with magic and witchcraft, a delusion favoured by the circumstance that some plants taken in by the mouth, extracted in ointments and applied to the skin, or smoked, caused vivid hallucinations. Inherited reminiscences of such ideas doubtless go far to explain the fascination which poisonous plants still have for most people. There is also the psychological factor that many of us have occasionally a strong urge to get away from ourselves and from the humdrum of ordinary life. To that urge, intoxicants and drugs offer an easy satisfaction; and from that arises that intractable problem which faces civilised governments of controlling the use of such noxious drugs as opium, hashish and cocaine. Yet addiction is not merely a human failing, arising from a state of mind; it must rest on a physiological foundation. Cattle and horses have an extraordinary liking for the foliage of yew, which is very harmful to them, and cattle which have recovered from poisoning caused by buttercups or oak leaves will strive obstinately to return to the bane. Addiction is more than human vice or frailty.

A poisonous plant must have certain features if it is to be dangerous to mankind. It must look attractive, especially in fruit, and it must generally resemble some wholesome plant in common use. To children, plants with handsome fruits (e.g. belladonna, yew) or plants with seeds which can be used in games as substitutes for sweets (e.g. laburnum) are the most dangerous. Young children, certainly, will put all sorts of things into their mouths, but they are unlikely to swallow sufficient of a poisonous leaf (most poisonous leaves have a nasty flavour) to cause more than transient trouble.

Careless, incautious or over-confident adults are a different matter. They are less likely than children to be deceived by attractive fruits, but they may meet trouble in gathering plants for use as seasoning or in a salad, as when the roots of monkshood are taken for horseradish, or when hemlock or fool's parsley is used in place of the true parsley. Fatal accidents of these kinds are on record, and infrequently death has followed the consumption of the roots of henbane or water dropwort as supposed parsnips.

Most of the plant poisons are irritants and cause inflammation, especially of the lining of the alimentary canal, with subsequent vomiting or purging; it may be that there is a connexion here with the dispersal of the seeds of the plant concerned. Biologically, they cannot be regarded wholly as a means of protecting the plant from the attacks of insects; the acrid juice of the poppy



HEMLOCK

DEADLY NIGHTSHADE

RAGWORT

CORNCOCKLE

does not keep away all aphids, and the poisonous yew is sometimes heavily attacked by the insect which provokes the formation of the common artichoke gall of that tree.

Chemically, plant poisons are diverse. Many of the best known are alkaloids; others are glycosides, saponins, resins, volatile oils, and so on. Some act directly on the brain or other organs of the victim, others develop from a harmless substance in the plant after it has been eaten.

The alkaloids are the most important poisons of vegetable origin, though all alkaloids are not poisonous. Several may occur in the same plant—there are five in hemlock (*Conium maculatum*) and twenty in the opium poppy (*Papaver somniferum*). Well-known alkaloids include: morphine from the opium poppy, nicotine from tobacco (*Nicotiana tabacum*), coniine from hemlock, atropine, hyoscyamine and hyoscine from belladonna —or deadly nightshade—(*Atropa belladonna*), henbane (*Hyoscyamus niger*) and thorn apple (*Datura stramonium*), taxine from yew (*Taxus baccata*), cytisine from laburnum (*Laburnum anagyroides*), jacobinine from ragwort (*Senecio jacobaea*), and strychnine from *Strychnos nux-vomica* (not a British plant). All these are virulent poisons. Alkaloids tend to be selective in action, affecting one organ or set of organs; morphine deals especially with the brain, cytisine, nicotine and coniine upset the respiratory system, aconitine and taxine the heart, and jacobinine destroys the liver. Atropine has a special action on the iris of the eye, and it, like nicotine, cystisine, hyoscine and hyoscyamine can be absorbed through the unbroken skin.

The opium poppy is commonly grown as an ornamental garden annual, and may be found as an escape. Opium is prepared from the milky juice of the plant (though the yield is uneconomic except in a warm climate) and morphia, a most valuable pain-reliever, from the crude opium. The red poppy is less poisonous and contains papaverine in place of morphine. The seeds of both poppies are wholesome and yield an edible oil, little inferior to olive oil.

Hemlock is common in rather damp situations: it is easily recognised by the red-spotted stems and leaf stalks, and by the mousy smell of the bruised plant. Its alkaloids, of which the chief is coniine, are, unlike those of many poisonous plants, dissipated by drying, so that hemlock is not dangerous in hay. Fatal accidents have followed the accidental use of the leaves in place of parsley. In the fourth century B.C., when Athens was at the height of its glory, hemlock was administered to criminals convicted of capital crimes; it caused a slow but merciful death: so Socrates died. Fool's parsley (*Aethusa cynapium*) also contains coniine, but in less amount, though sufficient to be dangerous. It has white flowers with two long bracts to each partial umbel, and smells foully when bruised; parsley has yellowish flowers, no long bracts, and a pleasant odour.

Deadly nightshade, henbane and thorn apple all belong to the same family of plants as tobacco, tomato and potato; the three are fortunately rather rare, as all are very poisonous. Of them, deadly nightshade (better called belladonna) is the most dangerous, as it has attractive fruits resembling small black cherries; three will kill a child. The plant is unlikely to be found except on limy soil in south Britain. It seems that rabbits can eat, without harm, sufficient of the plant to make their flesh fatally toxic to humans who may subsequently eat it. The plant has been used for a long time by ladies in southern Europe to make their eyes sparkle; it enlarges the iris. This accounts for the name "belladonna" which could well be substituted for deadly nightshade, the name commonly misused for the very abundant bittersweet (*Solanum dulcamara*), a hedgerow plant with bluish flowers and very elegant red berries. Bittersweet is somewhat poisonous and not good for children.

Black nightshade, a common garden weed, with white flowers and black berries resembling black-currants is rather a mystery. There are statements that children have died after eating the fruits, and there are statements that the fruits are little poisonous; it seems that

the wonderberry, a plant introduced by Burbank, was a form of black nightshade (*Solanum nigrum*). Black nightshade is certainly suspicious, and is best avoided. The green parts of potatoes and tomatoes contain solanine, which is a poison, but it is only accidentally greened tubers of the potato that might be a source of trouble. The use of green tomatoes for the preparation of chutney does not seem to have caused illness.

Monkshood (*Aconitum napeilus*) is common in gardens, rare as a wild plant. It is intensely poisonous, the aconitin it contains powerfully affecting the heart. No one is likely to eat the leaves and the fruits are unattractive; the roots have been mistaken for horseradish, with promptly fatal consequences.

Ragwort (*Senecio jacobœa*) is far too common in pastures. It is unlikely to poison human beings, as it has no features to attract them; but it has poisoned many cattle and some sheep. The alkaloid, jacobinine, is not destroyed by drying, so that the plant spoils hay. The liver of the victim is destroyed, and no remedy is known.

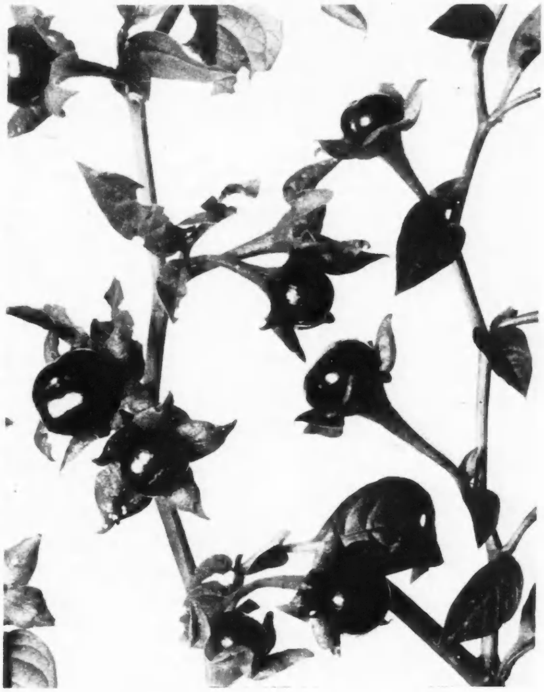
Yew is very poisonous to cattle, and because of the red fleshy cup around the base of the seed, is attractive to children. This cup (or aril) is not very poisonous, but children should be kept away from it, for there is a risk that they may swallow the seeds with the aril, and the seeds are very dangerous. They contain taxine, a powerful heart poison.

Glycosides are substances which break down to yield a sugar and some other substance, which may be poisonous. Some give prussic acid under these circumstances; such occur in the kernels of almonds, plums and related plants, in the leaves and grains of some of the grasses, and the leaves of white clover and other plants. Cattle have often been poisoned in this way. Pigs and man are less susceptible, but children have been poisoned by bitter almonds, and there are stories of wedding guests who have suffered after eating almond icing. Foxglove contains a different kind of glycoside, digitoxin, which appears to be poisonous of itself. Although the plant is very poisonous, it is unlikely to cause damage unless incautiously chewed, a not very probable event, for it has a nasty flavour.

Saponins, which are related chemically to the glycosides, destroy the red blood corpuscles. Plants containing saponins are not common in Britain. The best known is perhaps the corncockle (*Agrostemma githago*), a handsome weed of wheat-fields. At one time, flour contaminated with cockle seeds caused chronic poisoning, but this is now almost unknown.

Proto-anemonin is the commonest toxic volatile oil; it occurs in buttercups and some related plants. Cattle usually avoid buttercup plants because of their acrid flavour, and as the proto-anemonin decomposes to form an insoluble substance as the plant dries, hay containing buttercup is harmless. It may be remarked here that there is no substance in the old story that buttercups improve the quality of milk and butter: they make milk bitter.

Acorns as pig food are traditional, and it seems that except when the quantity is enormous, they are good



The berries of Deadly Nightshade.

for pigs. But they are harmful to cattle, as are the buds and leaves of the oak. The acrid bitter tannins not only injure the cattle, but taint both flesh and milk.

Some plant poisons are most dangerous when they enter the blood-stream. One group enter via the alimentary canal, and then make the animal liable to damage from strong light; it suffers from photo-sensitisation. Blonde or hairless animals are the usual sufferers. The liver is deranged, and ulcers may form on the skin. St. John's wort (*Hypericum perforatum*) buckwheat (*Fagopyrum esculentum*) and bog asphodel (*Narthecium ossifragum*) are proven or suspected causes of photo-sensitisation. Bog asphodel has long had a bad reputation among farmers, and its specific epithet—*ossifragum*—refers to a belief that it causes brittle bones in sheep. The plant occurs only on wet ground, and it is likely that damage ascribed to it may well be due to the unhealthy surroundings.

(Some of the facts in this article have been taken from *British Poisonous Plants* by A. A. Forsyth (Ministry of Agriculture and Fisheries, Bulletin No. 161, H.M. Stationery Office, 1954, 6*s*. 6*d*. net). Although the book was produced for the use of veterinarians and farmers, it can be read with profit by anyone who wants to know about the poisonous plants that cause most trouble in Britain, and to such it may be heartily commended. The drawings on p. 344 are reproduced from *Illustrations of the British Flora* by W. H. Fitch, by permission of the publishers, L. Reeve of Ashford.)

THE BOOKSHELF

Introduction to Nuclear Engineering

By Raymond L. Murray (*London, George Allen & Unwin, 1955, 418 pp., 30s.*)

The author subscribes to the view that the term "Nuclear Engineering" may be validly applied to the design, construction, testing and operation of equipment that makes use of, or relates to, nuclear processes and materials—particularly fissionable elements and their by-products. This being so, the reader will be surprised and disappointed to discover that this book by an American professor gives practically no information on chemical plant or chemical processes. Probably the reason is that although the American Atomic Energy Commission has released a considerable amount of information on nuclear reactors, the chemical processing of radioactive materials is still secret and the author has had to confine himself to declassified information.

The book is divided into sections dealing with the following subjects: Atomic and Nuclear Physics, Neutrons, Reactor Theory, Reactor Start-Up and Operation, Reactor Design Studies, Materials of Construction, Radiation Hazards, Shielding, Disposal of Radioactive Waste, Instrumentation and Neutron Experiments. The last few chapters are devoted to the uses of isotopes and possible methods of power production and utilisation. There are appendices on Reactor Theory and on Atomic and Nuclear Data.

The section on atomic and nuclear physics is an admirable attempt to make the book self-contained. Any engineer who has a good grounding in physics will find this chapter excellent for revision and recapitulation, but the conventional mechanical or electrical engineer who proposes to enter the atomic energy field will have to supplement this by wider reading. Since "half-life" is very important in all radioactive work, the mathematical treatment of rate of radioactive decay is given detailed attention.

Having dealt with the general properties of neutrons, the author develops the subject and discusses thermal neutrons, capture cross sections, neutron flux and thermal diffusion lengths, and then proceeds to fission and the chain reaction. Thus he builds up the essential background knowledge for the study of reactor principles and operation.

In the chapter on the separation of isotopes brief reference is made to the various methods employed, and there is a simple but instructive description of the gaseous diffusion cascade.

The types of materials required for reactor construction and operation are referred to, the desirable physical properties are listed and special reference is made to induced radioactivity and radiation damage. The treatment is necessarily brief, but it gives an indication of the requirements and the problems which are likely to occur.

After considering reactor principles, in which typical terms are defined and methods of calculating neutron flux, power and reactor dimensions are demonstrated, reactor start-up and operation are considered in some detail. The approach to criticality is well presented and the next is supplemented by two useful diagrams. The author emphasises that the principles of heat transfer and how to apply them are an important feature of reactor design and, therefore, devotes a short section to the fundamentals of heat transfer and fluid flow.

Concepts, calculations and materials appropriate to reactors are dealt with and then designs for a gas-cooled enriched uranium reactor and a liquid-metal-cooled natural uranium reactor are discussed. These designs may be rather theoretical and possibly impracticable but the reader will find them very valuable as exercises and they deserve very careful study.

In the section on radiation hazards, the general problem is presented, and there is a fairly detailed account of the effects of external radiation and the ingestion or inhalation of radioactive materials. The *roentgen* (r) is defined and it is shown how the conception was broadened to produce the unit called *roentgen equivalent physical* (r.e.p.). The method of calculating the maximum permissible concentration of a radioactive substance in drinking water is developed and applied to a specific example.

Shielding is discussed with particular reference to the conflicting requirements for effective shielding from neutrons and gamma radiation. Some account is given of the type of concrete used in the Brookhaven Reactor Shield.

The author refers to the types of radioactive wastes and the methods of disposing of them. Some of the methods are only of academic interest and this is brought out in the text "One of the recommendations of an Atomic Energy Commission Meeting in 1948 was that isotopes may be buried in ground owned by the user if the minimum depth is 5 feet and if they are diluted with an inert isotope of the same element. The degree of dilution must be such that the energy release is less than 4·15 ergs/g-day." In order to dispose of a millicurie of Na^{24} by this method it would be necessary to use 6750 kilograms of inert material!

Typical instruments which are used in the control and operation of reactors and some neutron experiments are described. The use of isotopes in chemistry, biology, medicine and industry is illustrated with simple examples. In the section on the possible uses of nuclear energy in various types of machines and for the large-scale production of electricity the advantages and disadvantages of nuclear fuel relative to conventional fuels are brought out.

At the end of each chapter there are problems which are designed for the student to use and to consolidate the knowledge he has obtained.

There are some elementary errors, e.g. on p. 63 speaking of the diffusion process it is stated "because of the continuous nature of this essentially chemical process" and on p. 98 "the Hanford Reactor is of the regenerative or breeder type". No doubt these errors will be corrected in the next edition.

It would be a considerable advantage if the book contained a glossary of terms and definitions.

The Government White Paper published recently indicates that the British atomic energy programme will expand considerably during the next few years. Consequently a large number of engineers, technicians and students will be entering this new field. To such people this book can be thoroughly recommended since it will provide for most of them sufficient theoretical knowledge to supplement their practical training in reactor technology.

Rutherford

By John Rowland (*London, Werner Lawrie, Shorter Lives Series, 1955, 160 pp., 10s. 6d.*)

The first thirty years of the 20th century have been called the heroic age of modern physics, and in that age the name of Rutherford stands supreme. His death in 1937 at the age of sixty-six came as a heavy blow to British science, and was all the more tragic in that it occurred so shortly before today's large-scale results had begun to flow from his work. The official biography by one of his former colleagues, the late Dr. A. S. Eve, is a massive volume published in 1939. There is room now after the earlier short works by Dr. Norman Feather and Ivor B. N. Evans for this concise and elementary Life which gives in brief outline the story of Rutherford's career.

One of the lasting benefits of the Great Exhibition of 1851, the only enterprise of its kind to make a substantial profit, has been the establishment of scholarships for outstanding students. It was through the award to him of one of these that Rutherford, after distinguishing himself brilliantly at Canterbury College, Christchurch, New Zealand, went to Cambridge in 1895 to work under J. J. Thomson at the Cavendish Laboratory. Twenty-four years later, when Thomson was Master of Trinity and unable to continue as Cavendish Professor of Experimental Physics, Rutherford succeeded

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him in the latter office, and these two great pioneers of atomic research worked amicably together in a relationship that might have proved difficult for lesser men.

In the intervening quarter-century Rutherford had acquired a truly colossal reputation. He had won the Nobel Prize for Chemistry in 1908 and had been knighted in 1914. Both at Montreal and at Manchester he had probed deeply into the problems of radioactivity, and the "Rutherford-Bohr atom", described in 1912, had pictured, in vivid terms that even the layman could appreciate, the new ideas on the structure of matter. As the leading experimental physicist of his time he had done, and was still to do, so much that his name remains a legend; and Mr. Rowland has condensed into a plain and readable narrative the salient features of his life, his character, and his achievements.

E. N. PARKER

Origin and Distribution of the British Flora

By J. R. Matthews (*London, Hutchinson's University Library, 1955, 173 pp., 8s. 6d.*)

This book, which appears at a time when professional botanists are probably devoting more attention to the study of British flowering plants than ever before, sets out to summarise the past and present distribution of these species and the relationships between the British flora and those of other countries. Cryptogams, even the vascular ones, are excluded from the discussion, and evolutionary problems are only incidentally mentioned. Within these rather artificial limits, the work will serve very well as an introduction to a field of study which has been too long neglected in elementary teaching. Although primarily designed as a university text, the book contains nothing which would make it unsuitable for use in sixth forms or by the amateur field worker.

Although Prof. Matthews has done as much as anybody could to make a connected narrative, the text is a little indigestible owing to the vast number of facts which have quite rightly been incorporated. It is unfortunate too that apart from a few distribution maps there are no illustrations, so that the reader must make his way amid the intricacies of pollen analysis and related topics without the encouragement of a single diagram.

The first hundred pages are mainly concerned with the changes which have taken place in the distribution of British plants from Eocene times to the present day. The facts are clearly presented, and the inferences which can be drawn from them are soberly and impartially assessed. This part of the work would have gained greatly if it had been possible to give a more extended and continuous account of the changes in climate and topography. It is a pity, for example, that the date of the inundation of the North Sea should be discussed without any indication that the additional water almost certainly came from the melting of the ice-sheets.

In later chapters the British flora as it exists today is subjected to analysis by the method of floristic "elements" of which the author has been one of the principal practitioners. Although the validity and importance of the facts are clearly beyond dispute, it is to be feared that the conclusions drawn from them will be viewed by any well-trained student with the gravest suspicion. Nor will his misgivings be allayed when he finds that all the "elements" taken together include much less than half of the species now growing in Britain. The prevailing climate of scientific opinion is decidedly unfavourable to arguments based on hand-picked data, carefully sorted into groups, and representing perhaps 35% of the available information.

Any writer attempting to interpret geographical distributions has to face the appalling dilemma raised by Willis. Either a species has occupied the area open to it, or it has not. In one case its range is a function of climate, in the other a function of time. Prof. Matthews leans heavily to the side of climatic explanations. It is a legitimate point of view even if, as one suspects may be the case, it is based on intuition rather than on any process of reasoning. In a textbook, however, it is regrettable that the great weight of evidence on the other side should be so summarily dismissed.

K. J. DORMER

Insects and Spiders. A Book of Keys with Biological Notes

By C. P. Friedlander and D. A. Priest (*London, Sir Isaac Pitman, 1955, 124 pp., 21 plates, 6s. 6d.*)

Few would deny that one of the chief difficulties of the biology teacher who seeks to give field-work its rightful place in middle- and upper-school classes is that of identifying the material collected. The book under review claims to be an attempt to meet this problem by presenting the classification of insects, spiders and harvestmen in a simple yet scientific manner that should be of use also in the first year of a general biology degree course and to the layman who is prepared to take more trouble than is required to follow some of the more popular books on identification. The lucid and simple style used throughout should commend itself to beginners. Use of a number of scientific terms is inevitable, however, and it is to be doubted whether there is any practical gain to offset the aesthetic disadvantage of translating "cephalothorax" into "head-thorax", and "femur", "tibia" and "tarsus" into "thigh", "shank" and "foot" respectively.

In view of the large number of species involved, any attempt at providing a simple guide for the identification of the British insect and arachnid fauna must inevitably fall short of an impossible ideal: in most cases this is by a very long way. Naturally there must be a tendency to ignore the smaller insects and spiders, many of which would in any case not be likely to attract the attention of the beginner; but to omit mention of all species less than half an inch in length, as has sometimes been done, is surely both unsatisfactory and unscientific. The authors of the present volume are therefore on firmer ground in their conviction that there is real value in identifying an insect as far as its family and a spider as far as its genus, for these divisions usually have ecological and economic significance and at the same time the exercise has educational value. Indeed, any attempt by the beginner at specific determination, except perhaps in the case of a few large and unmistakable forms, is both discouraging and unprofitable and the result of dubious value. Thus few spiders can be identified for certain without reference to their pedipalps and epigynes, yet although a number of species are here described these diagnostic characters are completely ignored. Again, there are forty-six species of Ephemeroptera on the British list, so that brief descriptions of two of the commonest of the larger species can be of little value; moreover this type of arbitrary selection may be grossly misleading. Similarly, keys to commoner genera only tend to create a feeling of uncertainty in the user who can never be certain that every possible alternative has been eliminated.

The diagnostic keys provided are simple and largely artificial, but the choice of characters is not always entirely happy: for example, where mouth-parts "some very long" are contrasted with mouth-parts "not particularly long"; while the locality in which a species is usually found surely should never have been introduced into an otherwise purely morphological key.

The book is illustrated by twenty-one plates of line drawings, crudely executed and not always quite accurate, but which nevertheless do succeed in conveying a very fair impression of the appearance of the types selected. The bibliography, limited to a score of titles, could with advantage have been much enlarged and the dates of publication of the volumes cited should have been given. Despite its shortcomings this book is well produced, convenient in size and very reasonably priced. It is definitely an improvement on anything of similar scope that has previously appeared.

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BOOK LIST

Radioisotopes Conference, 1954

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The Second Radioisotopes Conference organised by the Atomic Energy Research Establishment, Harwell, was held in July 1954. Its object was to discuss the latest experimental uses of radioisotopes and new techniques in their application to medicine, biology, agriculture, chemistry and physics, as well as to engineering and other industries.

In all, seventy papers were read, which, together with the ensuing discussions are published in two volumes. The first volume covers the application of radioisotopes to medicine, agriculture and the biological sciences; the second volume is concerned with the physical sciences and industrial applications.

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LETTERS TO THE EDITOR

Science and Adult Education

Sir:

Dr. Turner's article on Adult Education in Science (DISCOVERY, March 1955) and Dr. Kipling's letter (published in the June issue) reflect the general interest in this field which is so important for the future development of this "technological country". Tutorial classes in Physics have been run by the Extra-mural Studies Delegacy of this university without interruption for the last twelve years and some of the experience gained may be of interest to your readers.

The courses are run for three years each with twenty four meetings, lasting two hours, during the winter months. The work is being carried out at the University Physics Department and time is divided about equally between lectures plus discussion and laboratory work. Necessarily, lecturing is heavier in the beginning, and the courses finish eventually with twelve meetings of "free for all" experimenting at the end of the third year.

The original layout of the course was found to be sufficiently satisfactory so as not to require any drastic alteration. In the first few meetings a brief qualitative outline of the structure of matter is given, starting with a mention of the elementary particles and the way in which they aggregate to form atoms. Specimens of as many different elements as are available are shown, and their properties are explained with reference to the peripheral and nuclear properties of the atom. This can, of course, be done without introduction of complex terminology, and it does not require any knowledge of physical principles beyond such familiar concepts as attraction and repulsion. The realisation that the basic structure of all the diverse forms of matter is so simple and can be grasped so easily, always fascinates the class so much that there is very little tendency to leave the course again. Students, particularly those without any scientific background to start with, have frequently told me that the ability to form, after only one or two class meetings, reasonably clear ideas about the pattern of modern physics gave them all the confidence needed to embark on a three years' course.

The great opportunity in adult education to teach modern physics to begin with is often not sufficiently appreciated by the tutor. The last fifty years have brought an enormous conceptual unification of the phenomenology of our known physical world, and while this development is certainly far from complete, the complexity of observed facts has already been greatly reduced. It is therefore only reasonable to give the adult student straight away a glimpse of the picture as we see it today rather than to let him repeat laboriously the, often tortuous, path of historical development. To the person who knows no physics at all, a photon is no more unreal than a light wave and, in a world where matter is discrete the quantum concept of energy will appear to him more natural than the idea of a continuous energy fluid. I personally have always found it a good deal more enjoyable to teach the physics of today to these adult students than to instruct a class of undergraduates to be able to solve examination problems which were topical a hundred years ago. There is an unfortunate tendency to regard modern physics as "advanced" and therefore difficult, without realising that it is only advanced in respect to a system of classical physics which has become rigid by long acceptance.

Whereas teaching physics in the way as it has historically developed may have certain advantages in the training of professional physicists, it has little merit in adult education. While his powers of conclusive reasoning are strong, the receptivity of an adult student is much lower than when he was a schoolboy and the teaching of facts, especially facts which at the time appear unconnected, should be reduced to a minimum. Once he sees that the bewildering multiplicity of phenomena which appears to him as a hopelessly entangled puzzle can be reduced to a few principles, his enthusiasm and cooperation are assured. Since in the beginning the student has to take the tutor's word for the facts he is taught, it matters little whether these facts are classical or modern physics. On the other hand, to see that the formation of the chemical compound NaCl can be understood on the basis of the structure of the two atoms will arouse his interest in the subject a good deal more than being faced at the outset with a tedious derivation of the laws of motion under uniform acceleration. We have found that, once the adult students have been given a general survey of the pattern of modern physics, they are keen to learn the methods by which this knowledge had been gained.

The emphasis on modern physics at the beginning of the course has the added advantage that it acts as the great equaliser. Some members of a new class as it assembles will know a little physics from school, others none at all. Atomic structure and the properties of the elementary particles are new enough to all of them to give the whole class roughly the same start. The same class has had as its members tax inspectors, domestic servants, accountants, technicians, housewives, teachers and managers in business without offering an unfair advantage to any of them. The only section which has definitely stayed away from the classes are factory workers. Oxford's motor industry employs large numbers of unskilled but comparatively well-paid workers. The courses were brought to the notice of these men through the management, the trade unions and through specially arranged lectures in Cowley. However, all these efforts have failed to interest them in the science classes.

K. MENDELSSOHN

Clarendon Laboratory,
Oxford.

Relativity and the Order of Events

Sir:

The statement made by Mr. Chapman Pincher in his biographical sketch on Einstein (DISCOVERY, June 1955, page 231):

> "Events which appear in one order to one observer may appear in a different order to another, which upsets the idea that cause must precede effect."

needs a reply.

It is impossible for one observer to see as a later event one that is seen to be earlier by another observer; if event **B** is later than event **A** to one observer, it will generally be later to all observers. What the theory of relativity says is that events which are simultaneous to one observer may occur with a time interval to another moving relatively to the first; time intervals as measured by the first observer are generally different from those relating to the same events as measured by the second observer.

If Mr. Pincher does not believe this, he must try making t' negative in the time interval transformation formula of the special theory of relativity:

$$t' = \frac{t - vx/c^2}{(1 - v^2/c^2)^{\frac{1}{2}}}$$

This shows that when v (the relative velocity of the two observers) is 0, $t = t'$ and that when $v =$ the velocity of light, t' is infinite; no amount of working on this formula can make t' negative which is what it would have to be if one observer is to see events in a reverse order as compared with another. It is quite impossible for any observer to see the steam coming out of the kettle before the gas is lit!

M. A. PHILLIPS, D.Sc. (Lond.)

NEW SCIENTIFIC INSTRUMENTS

This new feature is designed to provide information about new scientific instruments which have come on the market. The detailed facts in it are the responsibility of the manufacturers, being taken from literature supplied by the makers. The editor will welcome information from manufacturers about new scientific instruments they are putting on the market. As these notes are intended for the large section of our readership composed of professional scientists, etc., we depart from our customary practice and use symbols and abbreviations to the full in order to be able to convey the maximum amount of detailed information.

Portable β–γ Radiation Monitor

The presence of uranium in mineral deposits can be detected from a distance by a Geiger counter because of the very penetrating γ-radiation it emits in its radioactive decay. A number of portable instruments for prospecting purposes have been produced, among which a recent introduction is the Panax Model 6950/c. This instrument of dimensions $10 \times 6 \times 4$ in. and weight 7 lb., has a large internally mounted Geiger counter (Type G.10.H) by 20th Century Electronics Ltd., which is of very robust design having an active length of 60 cm. with a cathode diameter of 30 mm. The voltage for the counter is fully stabilised. A socket is provided which automatically cuts out the internal tube when an external sensitive tube (Type B.6.H) is plugged in for use as a probe or in conjunction with a field assay unit. Indication is by a meter calibrated in two ranges 0–10,000 and 0–50,000 counts/min with a non-linear scale allowing very small amounts of radioactivity to be detected.

The instrument operates from a 67·5V standard h.t. battery, and three 1·5V cells. There is provision for the use of headphones.

Another model (6950/r) is calibrated in milliroentgens in two ranges 0–10 and 0–50 mr/h for gamma radiation measurements in connexion with health monitoring.

Panax Equipment Ltd., 173 London Road, Mitcham, Surrey.

Analogue Computer for Solving Differential Equations

The Miniputer illustrated here is a small electronic device for the solution of linear simultaneous differential equations, with time as the independent variable.

It is intended for educational purposes and for preliminary design investigations, such as those concerned with linear vibrations. There are two units: the power unit ($11 \times 16 \times 16$ in.) and the computer unit ($11 \times 16 \times 20\frac{1}{4}$ in.). The latter contains 10 amplifiers, each having a gain of $\times 1500$ and a band width of 12kc/s and each incorporating a sign reversing amplifier, 20 coefficient potentiometers of 50kΩ calibrated to an accuracy of 0·7% full scale. The solution is displayed on a double-beam 5-in. cathode-ray tube; the mode of operation is repetitive. Problems are put into the machine by plugging the necessary connecting links and passive components into the patch panel. Ten clamping valves are provided for discharging the computing capacitors automatically between scans. The power consumption is 320W from 200–250V at 50c/s.

Saunders-Roe Ltd., Electronics Division, Osborne, East Cowes, Isle of Wight.

Electronic Counter with Illuminated Display

Airmec's new counter, Type 865, is a high-speed electronic scaling unit operating at any speed up to a maximum of 1 million per second.

The display panel consist of 6 rows of 10 windows numbered from 0 to 10, each illuminated by a 6·3V 2W bulb, slightly under-run to ensure long life. It gives a direct reading of all counts up to 999,999, and is visible from a distance of 20 ft. The range of indication may be extended to 9,999 million by means of a non-resettable electro-mechanical counter.

The counter operates from signals of any wave form with peak amplitudes between 1·5 and 50V. A gating circuit enables the counting operation to be switched on or off either manually or by an external signal. There is provision for an external circuit to be made or broken at a predetermined count in the 0–999,999 range, and an output signal at every millionth count is also available. The instrument may be employed with auxiliary equipment for time, speed and frequency measurements.

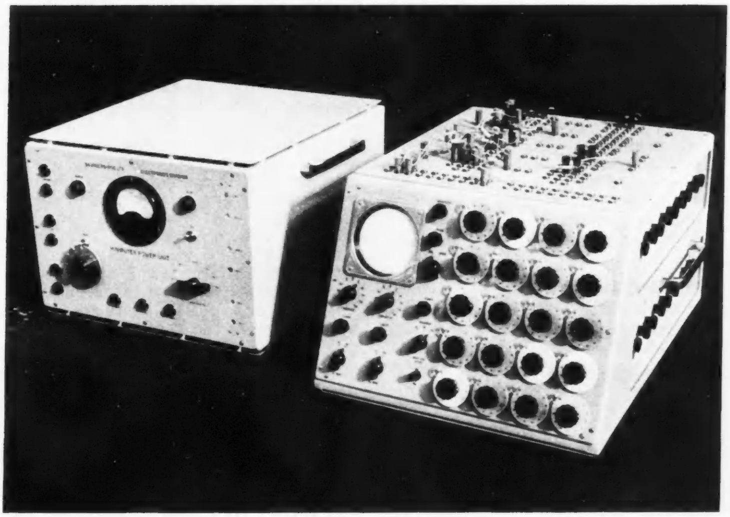
The electrical design is such that the operation of the counter does not depend on critical values of either components or mains supply voltage.

Airmec Ltd., High Wycombe, Bucks.

Thermostatic Hotplates

Townson and Mercer announce a new range of hotplates in which the expansion of the plate itself is balanced against an invar rod, giving thermostatic control through a micro-switch. The micro-switch regulator assembly controls the surface temperature of the plate to within about ± 3°C. A thermometer pocket is provided for direct reading of the surface temperature, if required. One model, intended for use on a retort stand, has a machined cast-iron top with a temperature range of 110°C–320°C. Other models are available, and similar ranges in aluminium alloy can be made up to 300°C and also low temperature types ranging from room temperature up to 150°C maximum. The temperature adjustment is made with a coin slot knob, not easily moved accidentally.

Townson & Mercer Ltd., Croydon, Surrey.



FAR AND NEAR

The Night Sky in August

The Moon.—Full moon occurs on August 3d 19h 30m U.T., and new moon on August 17d 19h 58m. The following conjunctions with the moon take place:

August		
19d 00h	Mercury in conjunction with the moon	Mercury 7° N.
24d 04h	Saturn ,,	Saturn 5° N.

The Planets.—*Mercury* is too close to the sun for observation in August. *Venus* rises about 45 minutes before sunrise up to the middle of the month and at the end of the month practically at the same time as sunrise, and is unfavourably placed for observation. *Mars* is in conjunction on August 17 and cannot be observed during the month. *Jupiter* is in conjunction on August 4 but can be observed towards the end of the month when it rises nearly 2 hours before the sun; it is in the eastern portion of Cancer and is moving towards Leo. *Saturn* sets at 23h, 22h 05m and 21h on August 1, 15 and 31 respectively, and can be observed in the constellation Libra; its slow eastward movement can be detected by comparing its positions during the month with the 2nd magnitude star α Librae from which it recedes.

The Perseid meteors are active during August, and attain a maximum about August 10–13. On August 10, 11, 12 and 13 the moon rises at 21h 45m, 22h 23m, 23h 14m and 0h respectively, and to some extent will interfere with observations of the shower.

Those who are trying to see the Perseid meteors will find some very interesting objects in this constellation. These include the star β Persei, generally named Algol, which is well known for its rapid changes in brightness. Two beautiful star clusters between η Persei and the constellation Cassiopeia are just visible to the naked eye and seen through binoculars or a small telescope present a wonderful sight; they never fail to excite the admiration of those who have not seen them before. Those who possess even a small optical aid can interest their friends in these clusters.

Britain's Weather Service

A new edition of the booklet *Your Weather Service* (H.M.S.O., 1*s.* 6*d.*) appears appropriately in 1955, which is the centenary year of the Meteorological Office. It describes how data is collected by thousands of expert meteorological observers on land and sea and in the air, and how, where and when the daily forecast bulletins are issued by the Meteorological Office. It gives details about the special forecasts which the Meteorological Office will supply to any organisation or individual for a modest fee. The appendices to this booklet include details of B.B.C. Sound and Television forecasting, a two-page table of Monthly Normal Temperatures for districts throughout the British Isles, and a list of phone numbers and addresses of Local Meteorological Offices (from which telephone inquirers can obtain the ordinary 24-hour forecast). Instructions are given as to how to send a reply-paid telegram (ten words plus one's address) to WEATHER TELEX LONDON to get a forecast direct from the Meteorological Office.

The Scientist and the Services

This subject was the theme of the speech delivered by SIR FREDERICK BRUNDRETT, Chief Scientific Adviser to the Ministry of Defence, at a recent luncheon of the Old Centralians. By scientist he said he meant not only physicists, mathematicians and chemists, but also design and development engineers.

It was the First World War that really taught the Services the necessity of employing the scientist. On that occasion they found they were up against an enemy who had put a very great deal of scientific effort into the development of his weapons and, as a result, both the Army, Navy and Air Force called in the scientist to help in a very large way.

When the war was over all three Services decided that they must maintain permanent scientific institutions to work on their weapons, and an appreciable number of experimental establishments were set up in various parts of the country, each dealing with a separate subject such as radio, submarine detection, gunnery and so on.

In the twenty years between the two wars, these establishments had a very hard life. They were continually under attack from the Treasury and in most cases their civilian scientists came under the direct executive control of military officers. Broadly speaking, up to 1939 the Services regarded the scientist purely and simply as a person to carry out orders in the design and development of new equipment. They were rarely consulted about the broader aspects of warfare. Sir Henry Tizard was one of the very few exceptions.

The Second World War altered all that, continued Sir Frederick. For one thing, practically all the leading scientists in the country flowed in to help. "These were people who had been accustomed to stating their views very freely under all circumstances. They were not rank-conscious, and it made little difference to them whether they were talking to a seaman or an admiral. They began to poke their noses into the ways in which weapons were used and they forced many changes in Service practice which had very beneficial results from the point of view of effect. This was particularly the case in air defence and in anti-submarine warfare. The success of these activities persuaded the military authorities that such people might have something to contribute in matters of tactics and even strategy, and the result was the appointment of very high-ranking scientists as Scientific Advisers to the Services."

The changes that took place in the status of the scientist during the war in the military departments were confirmed in the post-war organisation. A much more significant change was the emergence of a new method of conducting war. This was the Chiefs of Staff Committee Organisation for the Higher Conduct of the War, which was continued after the war, not only because the three Services were much more dependent upon each other than hitherto, but also because of the existence of NATO. When this organisation was reviewed at the end of the war, it was decided to incorporate in it an organisation for keeping under review the overall defence research and development programme, and a committee known as the Defence Research Policy Committee was set up in the Ministry of Defence to advise the Chiefs of Staff and the Minister of Defence on the proper allocation of effort over a fully integrated research and development programme.

This committee is under the chairmanship of a scientist and contains among its members all the authorities, both military and civilian, responsible for the statement of weapon requirements and for the work involved in producing the equipment to meet those requirements. Sir Frederick is the present chairman, and he told his audience that he has complete right of access to both the Chiefs of Staff and the Minister of Defence at any time he wishes and on any subject he wishes. Sir Frederick commented that the scientist is not only effectively represented at all levels in the Service Departments but he is also effectively represented at the top level in the controlling organisation for the formation of policy.

"The Services have shown a very open-minded approach to the problem of the integration of the scientists into their system. It is no longer true to say that the scientist works under the executive direction of service officers so far as his work is concerned. The situation today is that at all levels the scientist and the serving officer work together as partners, each carrying fully their own responsibilities. I do want to stress how very important it is that both partners should fully appreciate and respect the other's responsibilities.

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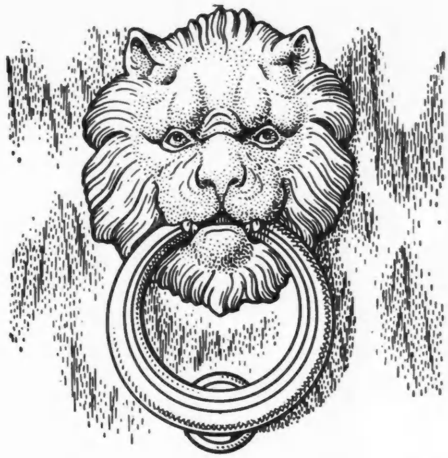

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Looked at from this point of view, I am of the opinion that today the military officer is if anything rather in advance of his scientific colleague. I personally believe that this country is ahead of the world in this matter and I am sure that these extremely beneficial arrangements have come to stay," concluded Sir Frederick.

Personal Notes

SIR ROBERT ROBINSON retires this summer from the Waynflete professorship of chemistry at Oxford, which he has held since 1931, and will be succeeded by PROF. E. R. H. JONES of Manchester University.

PROF. A. H. COTTRELL is leaving the Physical Metallurgy Department of Birmingham University to become deputy head of the Metallurgy Division at Harwell. The originality of his research work, which has mainly been on the plastic deformation of metal, was recognised by his election as an F.R.S. this year at the age of thirty-five.

DR. R. W. PICKFORD, who has been connected with the Psychology Department at Glasgow for over twenty-five years, becomes the first occupant of the chair of psychology in that university.

MR. GORDON C. INSKEEP, who has been representing the journals of the American Chemical Society in London (with offices in Bush House, Aldwych, London, W.C.2) has returned to the U.S.A. He is succeeded by MR. WILLIAM Q. HULL, a graduate chemical engineer.

The Linnean Society's Gold Medal has this year been awarded to SIR JOHN GRAHAM KERR, who was for thirty-three years Regius Professor of Natural History at Glasgow University.

DR. WILLIAM HOLMES has been appointed to the London University chair of agriculture at Wye College. A Glasgow graduate, he has been farm manager of the Hannah Dairy Research Institute where he did research on the application of heavy nitrogenous dressings to pasture.

DR. E. W. RUSSELL, reader in soil science, Department of Agriculture, University of Oxford, has been appointed director of the East African Agriculture and Forestry Research Organisation, in succession to Sir Bernard Keen, who has retired.

MR. D. A. DAVIES has been appointed Director-General of the World Meteorological Organisation.

DR. EDWARD W. YEMM succeeds PROF. MACGREGOR SKENE as Melville Wills Professor of Botany at Bristol University. He has been reader in the department since 1951.

Science Library Services

The Keeper of the Science Museum's library, which is generally called the Science Library, has drawn our attention to some inaccuracies in the section of the article (on p. 285) "The Search for Technical Information" referring to the services which this library provide. The price of the 1953 Handlist of Short Titles of Current Periodicals in the Science Library is 10*s.* (5*d.* postage), not 7*s.* 6*d.* The Loan Service for books and periodicals is confined to recognised approved institutes and organisations carrying out scientific or technical work; but the Photocopying Service is not restricted in this way—anyone can buy requisition forms for this service. Photocopy requisition forms (197 Sc.M.) for U.K. users are available at a cost of £7 10*s.* for a pad of fifty, or 4*s.* for a single form. Single forms may also be purchased in the Reading Room of the Science Library. Forms 208 Sc.M. for the Overseas Photocopying Service are issued in pads of twenty costing £4 each. Remittances for the forms should be sent to: The Director and Secretary, Science Museum, South Kensington, London, S.W.7.

We are also informed that the compilation of bibliographies free of charge for British inquirers is subject nowadays to considerable limitations.

"New Light on Photosynthesis"

In the Progress of Science note with this title published in the June issue, there was a diagram in the left-hand column of p. 227 showing the cyclic regeneration C_5 acceptor molecules. The top left arrow in this diagram should, of course, point in the opposite direction.

The Shortage of Patent Examiners

The latest report of Britain's Comptroller-General of Patents says that the arrears of unexamined specifications rose to 25,879 by the end of 1954. Owing to the shortage of patent examiners, the figure is increasing.

In a blunt statement issued by the Institution of Professional Civil Servants, the main reason for the reluctance of scientists to enter the Patent Office is the fact that they will have a less good career than scientists entering any other part of the Civil Service. The I.P.C.S. recognises that in a situation of shortage of scientific staffs generally, the Patent Office must have some difficulty in securing the staff it needs; the Board of Trade, however, makes this position unnaturally worse by offering poorer conditions than are obtainable not only elsewhere in the country but elsewhere in the Civil Service. Another factor that possibly deters would-be applicants from considering the Patent Office is the existence of the competitive entrance examination.

Six More Industrial-size Reactors for Britain

Britain's power programme providing for twelve atomic power stations at a cost of £300 million was announced in a White Paper in February (see "A New Industrial Revolution", DISCOVERY, April 1955, p. 136). The Atomic Energy Authority has now announced a substantial extension of that programme. Six more industrial-size reactors (costing about £60 million) are to be built, two of them at Calder Hall and the rest on the disused airfield at Chapelcross, near Annan, in Dumfriesshire. These reactors will feed power into the electric grid but their primary purpose is to provide plutonium, wanted for military purposes.

Rabbits' Immunity to Myxomatosis

The Minister of Agriculture stated in the House of Commons (June 16) that his department has examined surviving rabbits from many parts of the country and of these 39—or about 10%—were found to have acquired immunity to myxomatosis. He said that this immunity was not carried to the next generation, except possibly in the first few weeks of a young rabbit's life.

Toxic Chemicals in Agriculture: Risks to Wild Life

This is the title of the third report of the Government's Working Party "on precautionary measures against toxic chemicals used in agriculture", which deals with the dangers of these compounds to the wild life of Britain's countryside.

The outstanding points made in this document are as follows:

The direct mortality among wild birds and mammals from the use of toxic sprays is very low indeed. The sprays most likely to be harmful to wild birds and mammals, in order of danger are: organo-phosphorus insecticides applied to brassicas in late summer; arsenical compounds used for potato haulm destruction in September; dinitro weedkillers applied to corn and peas in spring and July; and DDT insecticides applied to orchards, carrots and peas. Dinitro weedkillers, such as DNC and dinoseb, if used properly and early in the season, will not cause heavy casualties. The hormone weedkillers the long-term effect of weedkillers on special precautions to ensure the safety of birds.

These chemicals affect the balance of insect populations more than they affect birds and mammals. Their hazard to bees is best met by methods other than legislation. Little is known about the long-term effect of weedkillers of the native flora, and the working party welcome experiments being made which should shed light on the changes that may follow the spraying of hedgerows and roadside verges. The final comment is: "Our inquiries have clearly shown how great are the gaps in our knowledge of the effects which the toxic chemicals used in agriculture may have on wild life, not to mention the possible consequential effects upon successful crop cultivation; and our pilot observations have indicated how well justified further field studies would be. There is a pressing need for more fundamental research."

The report is published by H.M.S.O. price 1*s.* 6*d.*

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